



McGuigan • Moyer • Harris

12th Edition

Managerial ECONOMICS

Application, Strategy, and Tactics

Managerial Economics

Applications, Strategy, and Tactics

TWELFTH EDITION

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**Managerial Economics: Applications,
Strategy, and Tactics, 12th Edition**

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To my family
J.R.M.

To Sally, Laura, and Craig
R.C.M.

To my family, Roger Sherman, and Ken Elzinga
F.H.B.H.

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Preface

ORGANIZATION OF THE TEXT

The 12th edition has been thoroughly updated with more than 50 new applications. Although shortened to 672 pages, the book still covers all previous topics. Responding to user request, we have expanded the review of microeconomic fundamentals in Chapter 2, employing a wide-ranging discussion of the equilibrium price of crude oil and gasoline. A new Appendix 7B on the Production Economics of Renewable and Exhaustible Natural Resources is complemented by a new feature on environmental effects and sustainability. A compact fluorescent lightbulb symbol highlights these discussions spread throughout the text. Another special feature is the extensive treatment in Chapter 6 of managing global businesses, import-export trade, exchange rates, currency unions and free trade areas, trade policy, and an extensive new section on China.

There is more comprehensive material on applied game theory in Chapter 13, 13A, 15, 15A, and Web Appendix D than in any other managerial economics textbook, and a unique treatment of yield (revenue) management appears in Chapter 14 on pricing. Part V includes the hot topics of corporate governance, information economics, auction design, and the choice of organization form. Chapter 16 on economic regulation includes a broad discussion of cap and trade policy, pollution taxes, and the optimal abatement of externalities. By far the most distinctive feature of the book, however, is its 300 boxed examples, Managerial Challenges, What Went Right/What Went Wrong explorations of corporate practice, and mini-case examples on every other page demonstrating what each analytical concept is used for in practice. This list of concept applications is highlighted on the inside front and back covers.

STUDENT PREPARATION

The text is designed for use by upper-level undergraduates and first-year graduate students in business schools, departments of economics, and professional schools of management, public policy, and information science as well as in executive training programs. Students are presumed to have a background in the basic principles of microeconomics, although Chapter 2 offers an extensive review of those topics. No prior work in statistics is assumed; development of all the quantitative concepts employed is self-contained. The book makes occasional use of elementary concepts of differential calculus. In all cases where calculus is employed, at least one alternative approach, such as graphical, algebraic, or tabular analysis, is also presented. Spreadsheet applications have become so prominent in the practice of managerial economics that we now address optimization in that context.

PEDAGOGICAL FEATURES OF THE 12TH EDITION

The 12th edition of *Managerial Economics* makes extensive use of pedagogical aids to enhance individualized student learning. The key features of the book are:

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1. **Managerial Challenges.** Each chapter opens with a Managerial Challenge (MC) illuminating a real-life problem faced by managers that is closely related to the topics covered in the chapter. Instructors can use the new discussion questions following each MC to “hook” student interest at the start of the class or in pre-class preparation assignments.
2. **What Went Right/What Went Wrong.** This feature allows students to relate business mistakes and triumphs to what they have just learned, and helps build that elusive goal of managerial insight.
3. **Extensive Use of Boxed Examples.** More than 300 real-world applications and examples derived from actual corporate practice are highlighted throughout the text. These applications help the analytical tools and concepts to come alive and thereby enhance student learning. They are listed on the inside front and back covers to highlight the prominence of this feature of the book.
4. **Environmental Effects Symbol.** A CFL bulb symbol highlights numerous passages throughout the book that address environmental effects and sustainability.
5. **Exercises.** Each chapter contains a large problem analysis set. Check answers to selected problems color-coded in blue type are provided in Appendix C at the end of the book. Problems that can be solved using Excel are highlighted with an Excel icon. The book’s Web site (www.cengage.com/economics/mcguigan) has answers to all the other textbook problems.
6. **Case Exercises.** Most chapters include mini-cases that extend the concepts and tools developed into a deep fact situation context of a real-world company.
7. **Chapter Glossaries.** In the margins of the text, new terms are defined as they are introduced. The placement of the glossary terms next to the location where the term is first used reinforces the importance of these new concepts and aids in later studying.
8. **International Perspectives.** Throughout the book, special International Perspectives sections are provided that illustrate the application of managerial economics concepts to an increasingly global economy. A globe symbol highlights this internationally-relevant material.
9. **Point-by-Point Summaries.** Each chapter ends with a detailed, point-by-point summary of important concepts from the chapter.
10. **Diversity of Presentation Approaches.** Important analytical concepts are presented in several different ways, including tabular analysis, graphical analysis, and algebraic analysis to individualize the learning process.

ANCILLARY MATERIALS

A complete set of ancillary materials is available to adopters to supplement the text, including the following:

Instructor’s Manual and Test Bank

Prepared by Richard D. Marcus, University of Wisconsin–Milwaukee, the instructor’s manual and test bank that accompany the book contain suggested answers to the end-of-chapter exercises and cases. The authors have taken great care to provide an error-free manual for instructors to use. The manual is available to instructors on the book’s Web site as well as on the Instructor’s Resource CD-ROM (IRCD). The test bank, containing a large collection of true-false, multiple-choice, and numerical problems, is available to adopters and is also available on the Web site in Word format, as well as on the IRCD.

ExamView

Simplifying the preparation of quizzes and exams, this easy-to-use test creation software includes all of the questions in the printed test bank and is compatible with Microsoft Windows. Instructors select questions by previewing them on the screen, choosing them randomly, or picking them by number. They can easily add or edit questions, instructions, and answers. Quizzes can also be created and administered online, whether over the Internet, a local area network (LAN), or a wide area network (WAN).

Textbook Support Web Site

When you adopt *Managerial Economics: Applications, Strategy, and Tactics*, 12e, you and your students will have access to a rich array of teaching and learning resources that you won't find anywhere else. Located at www.cengage.com/economics/mcguigan, this outstanding site features additional Web Appendices including appendices on indifference curve analysis of consumer choice, international parity conditions, linear programming applications, a capacity planning entry deterrence case study, joint product pricing and transfer prices, and decision making under uncertainty. It also provides links to additional instructor and student resources including a "Talk-to-the-Author" link.

PowerPoint Presentation

Available on the product companion Web site, this comprehensive package provides an excellent lecture aid for instructors. Prepared by Richard D. Marcus at the University of Wisconsin–Milwaukee, these slides cover many of the most important topics from the text, and they can be customized by instructors to meet specific course needs.

CourseMate

Interested in a simple way to complement your text and course content with study and practice materials? Cengage Learning's Economics CourseMate brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. Watch student comprehension soar as your class works with the printed textbook and the textbook-specific Web site. Economics CourseMate goes beyond the book to deliver what you need! You and your students will have access to ABC/BBC videos, Cengage's EconApps (such as EconNews and EconDebate), unique study guide content specific to the text, and much more.

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Fundamental Economic Concepts

CHAPTER PREVIEW A few fundamental microeconomic concepts provide cornerstones for all of the analysis in managerial economics. Four of the most important are demand and supply, marginal analysis, net present value, and the meaning and measurement of risk. We will first review how the determinants of demand and supply establish a market equilibrium price for gasoline, crude oil, and hybrid electric cars. Marginal analysis tools are central when a decision maker is seeking to optimize some objective, such as maximizing cost savings from changing a lightbulb (e.g., from normal incandescent to compact fluorescent [CFL]). The net present value concept makes directly comparable alternative cash flows occurring at different points in time. In so doing, it provides the linkage between the timing and risk of a firm's projected profits and the shareholder wealth-maximization objective. Risk-return analysis is important to an understanding of the many trade-offs that managers must consider as they introduce new products, expand capacity, or outsource overseas in order to increase expected profits at the risk of greater variation in profits.

Two Web appendices elaborate these topics for those who want to know more analytical details and seek exposure to additional application tools. Web Appendix 2A develops the relationship between marginal analysis and differential calculus. Web Appendix 2B shows how managers incorporate explicit probability information about the risk of various outcomes into individual choice models, decision trees, risk-adjusted discount rates, simulation analysis, and scenario planning.

MANAGERIAL CHALLENGE

Why Charge \$25 per Bag on Airline Flights?

In May 2008, American Airlines (AA) announced that it would immediately begin charging \$25 per bag on all AA flights, not for extra luggage but for the first bag! Crude oil had doubled from \$70 to \$130 per barrel in the previous 12 months, and jet fuel prices had accelerated even faster. AA's new baggage policy applied to all ticketed passengers except first class and business class. On top of incremental airline charges for sandwiches and snacks

introduced the previous year, this new announcement stunned the travel public. Previously, only a few deep-discount U.S. carriers with very limited route structures such as People Express had charged separately for both food and baggage service. Since American Airlines and many other major carriers had belittled that policy as part of their overall marketing campaign against deep discounters, AA executives faced a dilemma.

Cont.

MANAGERIAL CHALLENGE *Continued*

Jet fuel surcharges had recovered the year-over-year average variable cost increase for jet fuel expenses, but incremental variable costs (the marginal cost) remained uncovered. A quick back-of-the-envelope calculation outlines the problem. If total variable costs for a 500-mile flight on a 180-seat 737-800 rise from \$22,000 in 2007 Q2 to \$36,000 in 2008 Q2 because of \$14,000 of additional fuel costs, then competitively priced carriers would seek to recover $\$14,000/180 = \78 per seat in jet fuel surcharges. The average variable cost rise of \$78 would be added to the price for each fare class. For example, the \$188 Super Saver airfare restricted to 14-day advance purchase and Saturday night stay overs would go up to \$266. Class M airfares requiring 7-day advance purchase but no Saturday stay overs would rise from \$289 to \$367. Full coach economy airfares without purchase restrictions would rise from \$419 to \$497, and so on.

The problem was that by 2008 Q2, the marginal cost for jet fuel had risen to approximately \$1 for each pound transported 500 miles. Carrying an additional 170-pound passenger in 2007 had resulted in \$45 of additional fuel costs. By May 2008, the marginal fuel cost was $\$170 - \$45 = \$125$ higher! So although the \$78 fuel surcharge was offsetting the accounting expense increase when one averaged in cheaper earlier fuel purchases, additional current purchases were much more expensive. It was this much higher \$170 marginal cost that managers realized they should focus upon in deciding upon incremental seat sales and deeply discounted prices.

And similarly, this marginal \$1 per pound for 500 miles became the focus of attention in analyzing baggage cost. A first suitcase was traveling free under the prior baggage policy as long as it weighed less than 42 pounds. But that maximum allowed suitcase imposed \$42 of marginal cost in May 2008. Therefore, in



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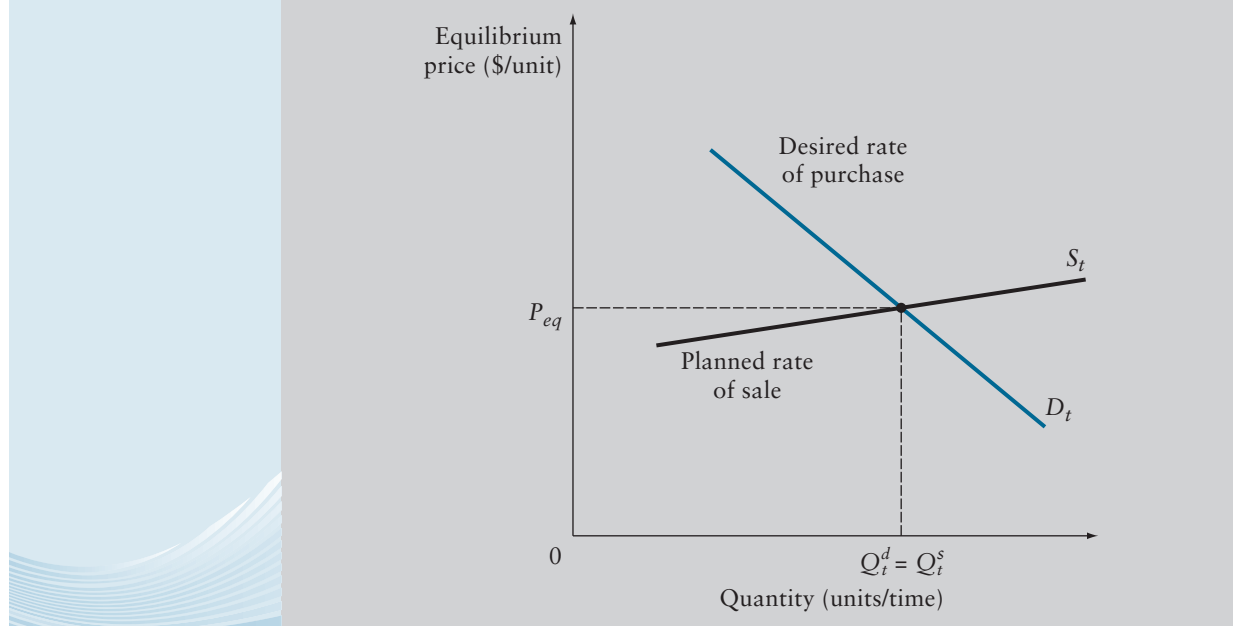
mid-2008, American Airlines (and now other major carriers) announced a \$25 baggage fee for the first bag in order to cover the marginal cost of the representative suitcase on AA, which weighs 25.4 pounds.

Discussion Questions

- How should the airline respond when presented with an overweight bag (more than 42 pounds)?
- Explain whether or not each of the following should be considered a variable cost that increases with each additional airline seat sale: baggage costs, crew costs, commissions on ticket sales, airport parking costs, food costs, and additional fuel costs from passenger weight.
- If jet fuel prices reverse their upward trend and begin to decline, fuel surcharges based on average variable cost will catch up with and surpass marginal costs. How should the airlines respond then?

DEMAND AND SUPPLY: A REVIEW

Demand and supply simultaneously determine equilibrium market price (P_{eq}). P_{eq} equates the desired rate of purchase Q_d/t with the planned rate of sale Q_s/t . Both concepts address intentions—that is, purchase intentions and supply intentions. Demand is therefore a potential concept often distinguished from the transactional event of “units sold.” In that sense, demand is more like the potential sales concept of customer traffic than it is the accounting receivables concept of revenue from completing an actual sale. Analogously, supply is more like scenario planning for operations than it is like actual

FIGURE 2.1 Demand and Supply Determine the Equilibrium Market Price

production, distribution, and delivery. In addition, supply and demand are explicitly rates per unit time period (e.g., autos per week at a Chevy dealership and the aggregate purchase intentions of the households in the surrounding target market). Hence, P_{eq} is a market-clearing equilibrium concept, a price that equates the flow rates of intended purchase and planned sale.

When the order flow to buy at a given price (Q_d/t) in Figure 2.1 just balances against the order flow to sell at that price (Q_s/t), P_{eq} has emerged, but what ultimately determines this metric of “value” in a marketplace? Among the earliest answers can be found in the Aristotelian concept of intrinsic use value. Because diamonds secure marriage covenants and peace pacts between nations, they provide enormous use value and should therefore exhibit high market value. The problem with this theory of value taken alone arises when one considers cubic zirconium diamonds. No one other than a jewel merchant can distinguish the artificial cubic zirconium from the real thing, and therefore the intrinsic uses of both types are identical. Yet, cubic zirconium diamonds sell for many times less than natural stones of like grade and color. Why? One clue arose at the end of the Middle Ages, when Catholic monasteries produced beautiful hand-copied Bibles and sold them for huge sums (i.e., \$22,000 in 2010 dollars) to other monasteries and the nobility. In 1455, Johannes Guttenberg offered a “mass produced” printed facsimile that could be put to exactly the same intrinsic use, and yet, the market value fell almost one-hundred-fold to \$250 in 2010 dollars. Why?

Equilibrium market price results from the interaction of demanders and suppliers involved in an exchange. In addition to the use value demanders anticipate from a product, a supplier’s variable cost will also influence the market price observed. Ultimately, therefore, what minimum asking price suppliers require to cover their variable costs is just as pivotal in determining value in exchange as what maximum offer price buyers are willing to pay. Guttenberg Bibles and cubic zirconium diamonds exchange in a marketplace at lower “value” not because they are intrinsically less useful than prior copies of the Bible

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or natural stones but simply because the bargain struck between buyers and sellers of these products will likely be negotiated down to a level that just covers their lower variable cost plus a small profit. Otherwise, preexisting competitors are likely to win the business by asking less.

Even when the cost of production is nearly identical and intrinsic use value is nearly identical, equilibrium market prices can still differ markedly. One additional determinant of value helps to explain why. Market value depends upon the relative scarcity of resources. Hardwoods are scarce in Japan but plentiful in Sweden. Even though the cost of timber cutting and sawmill planing is the same in both locations, hardwood trees have scarcity value as raw material in Japan that they do not have in Sweden where they are plentiful. To take another example, whale oil for use in lamps throughout the nineteenth and early twentieth centuries stayed at a nearly constant price until whale species began to be harvested at rates beyond their sustainable yield. As whale resources became scarcer, the whalers who expended no additional cost on better equipment or longer voyages came home with less oil from reduced catches. With less raw material on the market, the input price of whale oil rose quickly. Consequently, despite unchanged other costs of production, the scarcer input led to a higher final product price. Similar results occur in the commodity market for coffee beans or orange juice when climate changes or insect infestations in the tropics cause crop projections to decline and scarcity value to rise.

Example

Discovery of Jojoba Bean Causes a Collapse of Whale Oil Lubricant Prices¹

Until the last decade of the twentieth century, the best-known lubricant for high-friction machinery with repeated temperature extremes like fan blades in aircraft jet engines, contact surfaces in metal cutting tools, and gearboxes in auto transmissions was a naturally occurring substance—sperm whale oil. In the early 1970s, the United States placed sperm whales on the endangered species list and banned their harvest. With the increasing scarcity of whales, the world market price of whale oil lubricant approached \$200 per quart. Research and development for synthetic oil substitutes tried again and again but failed to find a replacement. Finally, a California scientist suggested the extract of the jojoba bean as a natural, environmentally friendly lubricant. The jojoba bean grows like a weed throughout the desert of the southwestern United States on wild trees that can be domesticated and cultivated to yield beans for up to 150 years.

After production ramped up from 150 tons in 1986 to 700 tons in 1995, solvent-extracted jojoba sold for \$10 per quart. When tested in the laboratory, jojoba bean extract exhibits some lubrication properties that exceed those of whale oil (e.g., thermal stability over 400°F). Although 85 to 90 percent of jojoba bean output is used in the production of cosmetics, the confirmation of this plentiful substitute for high-friction lubricants caused a collapse in whale lubricant prices. Sperm whale lubricant has the same cost of production and the same use value as before the discovery of jojoba beans, but the scarcity value of the raw material input has declined tenfold. Consequently, a quart of sperm whale lubricant now sells for under \$20 per quart.



¹Based on “Jojoba Producers Form a Marketing Coop,” *Chemical Marketing Reporter* (January 8, 1995), p. 10.

The Diamond-Water Paradox and the Marginal Revolution

So equilibrium price in a marketplace is related to (1) intrinsic use value, (2) production cost, and (3) input scarcity. In addition, however, most products and services have more than one use and more than one method of production. And often these differences relate to how much or how often the product has already been consumed or produced. For example, the initial access to e-mail servers or the Internet for several hours per day is often essential to maintaining good communication with colleagues and business associates. Additional access makes it possible to employ search engines such as Google for information related to a work assignment. Still more access affords an opportunity to meet friends in a chat room. Finally, some households might purchase even more hours of access on the chance that a desire to surf the Web would arise unexpectedly. Each of these uses has its own distinct value along a continuum starting with necessities and ending with frivolous non-essentials. Accordingly, what a customer will pay for another hour of Internet access depends on the incremental hour in question. The greater the utilization already, the lower the use value remaining.

marginal use value The additional value of the consumption of one more unit; the greater the utilization already, the lower the use value remaining.

This concept of a **marginal use value** that declines as the rate of consumption increases leads to a powerful insight about consumer behavior. The question was posed: “Why should something as essential to human life as water sell for low market prices while something as frivolous as cosmetic diamonds sell for high market prices?” The initial answer was that water is inexpensive to produce in most parts of the world while diamonds require difficult search and discovery, expensive mining, and extensive transportation and security expenses. In other words, diamonds cost more than water, so minimum asking prices of suppliers dictate the higher market value observed for diamonds. However, recall that supply is only one of what Alfred Marshall famously called “two blades of the scissors” representing demand and supply. You can stab with one blade but you can’t cut paper, and using supply alone, you can’t fully explain equilibrium market price.

marginal utility The use value obtained from the last unit consumed.

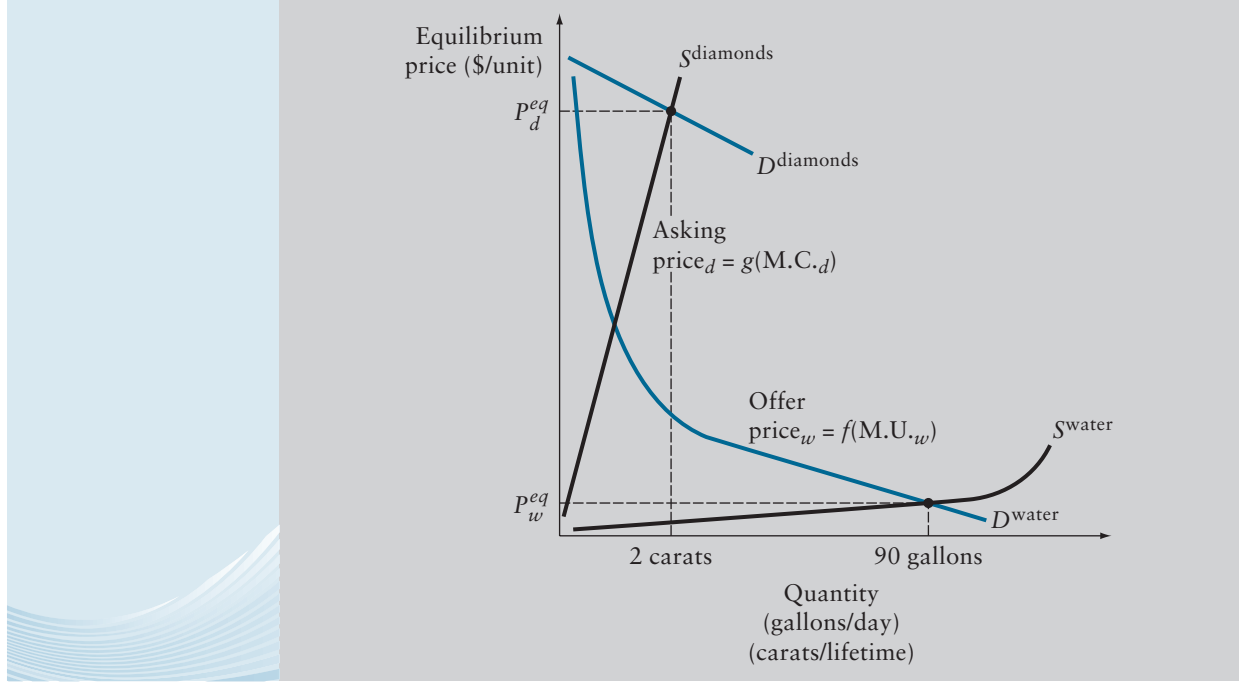
The diamond-water paradox was therefore restated more narrowly: “Why should consumers bid low offer prices for something as essential as water while bidding high offer prices for something as frivolous as diamonds?” The resolution of this narrower paradox hinges on distinguishing marginal use value (**marginal utility**) from total use value (total utility). Clearly, in some circumstances and locales, the use value of water is enormous. At an oasis in the desert, water does prevent you from thirsting to death. And even in the typical city, the first couple of ounces of some liquid serve this same function, but that’s the first couple of ounces. The next couple of dozen gallons per day remain at high use value for drinking, flushing indoor plumbing, cooking, body washing, and so forth. Thereafter, water is used for clothes washing, landscape watering, car washing, and sundry lesser purposes. Indeed, if one asks the typical American household (which consumes 80–100 gallons per person per day) to identify its least valuable use of water each day, the answer may come back truly frivolous—perhaps something like the water that runs down the sink drain while brushing teeth. In other words, the *marginal use value* of water in most developed countries is the water that saves the consumer the inconvenience of turning the water taps (on and off) twice rather than just once. And it is this marginal use value at the relevant margin, not the total utility across all uses, that determines a typical water consumer’s meager willingness to pay.

Marginal Utility and Incremental Cost Simultaneously Determine Equilibrium Market Price

Alfred Marshall had it right: demand and supply do simultaneously determine market equilibrium price. On the one hand, marginal utility determines the maximum offer

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FIGURE 2.2 The Diamond-Water Paradox Resolved



price consumers are willing to pay for each additional unit of consumption on the demand side of the market. On the other hand, variable cost at the margin (an incremental cost concept sometimes referred to as “marginal cost”) determines the minimum asking price producers are willing to accept for each additional unit supplied. Water is both cheaper to produce and more frivolous than diamonds *at the relevant margin*, and hence water’s market equilibrium price is lower than that of diamonds. Figure 2.2 illustrates this concept of marginal use value for water varying from the absolutely essential first few ounces to the frivolous water left running while brushing one’s teeth.

At the same time, the marginal cost of producing water remains low throughout the 900-gallon range of a typical household’s consumption. In contrast, diamonds exhibit steeply rising marginal cost even at relatively small volume, and customers continue to employ cosmetic diamonds for highly valuable uses even out to the relevant margin (one to three carats) where typical households find their purchases occurring. Therefore, diamonds *should* trade for equilibrium market prices that exceed the equilibrium market price of water.

Individual and Market Demand Curves

We have seen that the market-clearing equilibrium price (P_{eq}) that sets the desired rate of purchase (Q_d/t) equal to the planned rate of sale (Q_s/t) is simultaneously both the maximum offer price demanders are willing to pay (the “offer”) and the minimum asking price sellers are willing to accept (the “ask”). But what determines the desired rate of purchase Q_d/t and planned rate of sales Q_s/t ? The demand schedule (sometimes called the “demand curve”) is the simplest form of the demand relationship. It is merely a list of prices and corresponding quantities of a commodity that would be demanded by some individual or group of individuals at uniform prices. Table 2.1 shows the demand schedule for regular-size pizzas at a Pizza Hut restaurant. This demand schedule

TABLE 2.1 SIMPLIFIED DEMAND SCHEDULE: PIZZA HUT RESTAURANT

PRICE OF PIZZA (\$/UNIT)	QUANTITY OF PIZZAS SOLD (UNITS PER TIME PERIOD)
10	50
9	60
8	70
7	80
6	90
5	100

indicates that *if* the price were \$9.00, customers would purchase 60 per night. Note that the lower the price, the greater the quantity that will be demanded. This is the strongest form of the law of demand—if a product or service is income superior, a household will always purchase more as the relative price declines.

The Demand Function

The demand schedule (or curve) specifies the relationship between prices and quantity demanded, *holding constant the influence of all other factors*. A **demand function** specifies all these other factors that management will often consider, including the design and packaging of products, the amount and distribution of the firm’s advertising budget, the size of the sales force, promotional expenditures, the time period of adjustment for any price changes, and taxes or subsidies. As detailed in Table 2.2, the demand function for hybrid-electric or all-electric autos can be represented as

$$Q_D = f(P, P_S, P_C, Y, A, A_C, N, C_P, P_E, T_A, T/S \dots) \quad [2.1]$$

where Q_D = quantity demanded of (e.g., Toyota Prius or Chevy Volt)

P = price of the good or service (the auto)

P_S = price of **substitute goods** or services (e.g., the popular gasoline-powered Honda Accord or Chevy Malibu)

P_C = price of **complementary goods** or services (replacement batteries)

Y = income of consumers

A = advertising and promotion expenditures by Toyota, Honda, and General Motors (GM)

A_C = competitors’ advertising and promotion expenditures

N = size of the potential target market (demographic factors)

C_P = consumer tastes and preferences for a “greener” form of transportation

P_E = expected future price appreciation or depreciation of hybrid autos

T_A = purchase adjustment time period

T/S = taxes or subsidies on hybrid autos

The demand schedule or demand curve merely deals with the price-quantity relationship itself. *Changes in the price (P) of the good or service will result only in movement along the demand curve, whereas changes in any of the other demand determinants in the demand function ($P_S, P_C, Y, A, A_C, N, C_P, P_E$, and so on) shift the demand curve.* This is illustrated graphically in Figure 2.3. The initial demand relationship is line DD' . If the

demand function

A relationship between quantity demanded and all the determinants of demand.



substitute goods

Alternative products whose demand increases when the price of the focal product rises.

complementary goods

Complements in consumption whose demand decreases when the price of the focal product rises.

TABLE 2.2 PARTIAL LIST OF FACTORS AFFECTING DEMAND

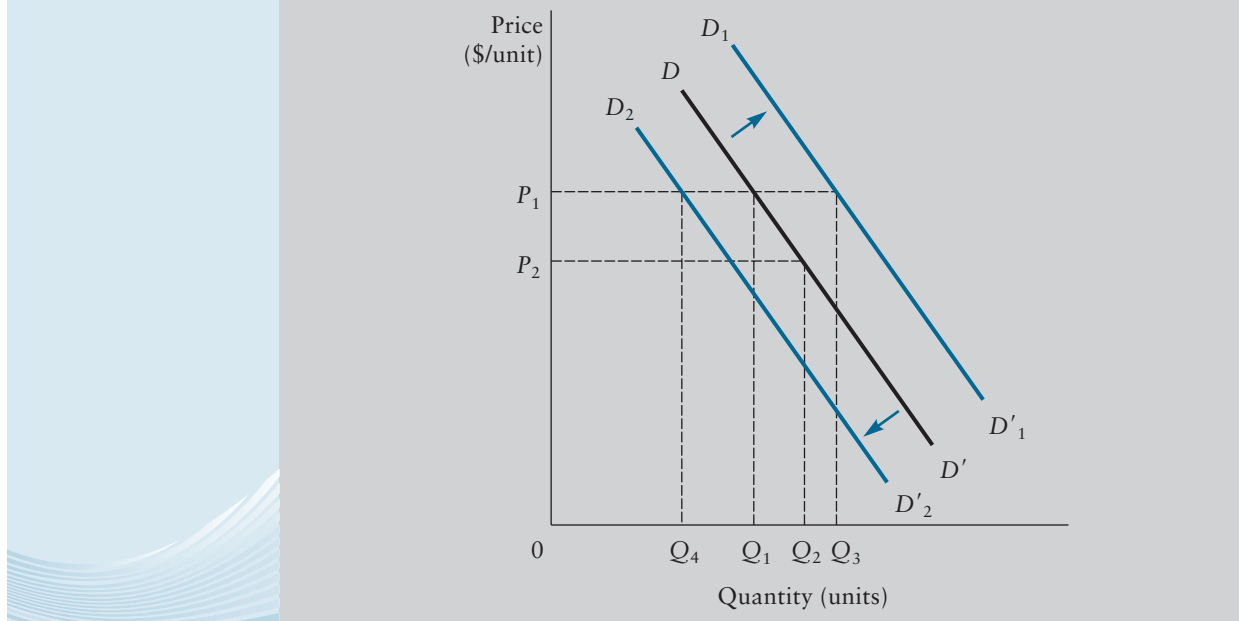
DEMAND FACTOR	EXPECTED EFFECT
Increase (decrease) in price of substitute goods ^a (P_S)	Increase (decrease) in demand (Q_D)
Increase (decrease) in price of complementary goods ^b (P_C)	Decrease (increase) in Q_D
Increase (decrease) in consumer income levels ^c (Y)	Increase (decrease) in Q_D
Increase (decrease) in the amount of advertising and marketing expenditures (A)	Increase (decrease) in Q_D
Increase (decrease) in level of advertising and marketing by competitors (A_C)	Decrease (increase) in Q_D
Increase (decrease) in population (N)	Increase (decrease) in Q_D
Increase (decrease) in consumer preferences for the good or service (C_P)	Increase (decrease) in Q_D
Expected future price increases (decreases) for the good (P_E)	Increase (decrease) in Q_D
Time period of adjustment increases (decreases) (T_A)	Increase (decrease) in Q_D
Taxes (subsidies) on the good increase (decrease) (T/S)	Decrease (increase) in Q_D

^aTwo goods are substitutes if an increase (decrease) in the price of Good 1 results in an increase (decrease) in the quantity demanded of Good 2, holding other factors constant, such as the price of Good 2, other prices, income, and so on, or vice versa. For example, margarine may be viewed as a rather good substitute for butter. As the price of butter increases, more people will decrease their consumption of butter and increase their consumption of margarine.

^bGoods that are used in conjunction with each other, either in production or consumption, are called *complementary goods*. For example, DVDs are used in conjunction with DVD players. An increase in the price of DVD players would have the effect of decreasing the demand for DVDs, *ceteris paribus*. In other words, two goods are complementary if a decrease in the price of Good 1 results in an increase in the quantity demanded of Good 2, *ceteris paribus*. Similarly, two goods are complements if an increase in the price of Good 1 results in a decrease in the quantity demanded of Good 2.

^cThe case of inferior goods—that is, those goods that are purchased in smaller total quantities as income levels rise—will be discussed in Chapter 3.

FIGURE 2.3 Shifts in Demand



original price were P_1 , quantity Q_1 would be demanded. If the price declined to P_2 , the quantity demanded would increase to Q_2 . If, however, changes occurred in the other determinants of demand, we would expect to have a shift in the entire demand curve. If, for example, a subsidy to hybrids were enacted, the new demand curve might become $D_1D'_1$. At any price, P_1 , along $D_1D'_1$, a greater quantity, Q_3 , will be demanded than at the same price before the subsidy on the original curve DD' . Similarly, if the prices of substitute products such as the Honda Accord or Chevy Malibu were to decline sharply, the demand curve would shift downward and to the left. At any price, P_1 , along the new curve $D_2'D_2$, a smaller quantity, Q_4 , would be demanded than at the same price on either DD' or $D_1D'_1$.

In summary, movement *along* a demand curve is often referred to as a *change in the quantity demanded*, while holding constant the effects of factors other than price that determine demand. In contrast, a shift of the entire demand curve is often referred to as a *change in demand* and is always caused by some demand determinant other than price.

Import-Export Traded Goods

In addition to the previous determinants of demand, the demand for goods traded in foreign markets is also influenced by external factors such as exchange rate fluctuations. When Microsoft sells computer software overseas, it prefers to be paid in U.S. dollars. This is because a company like Microsoft incurs few offshore expenses beyond advertising and therefore cannot simply match payables and receivables in a foreign currency. To accept euros, Japanese yen, or Australian dollars in payment for software purchase orders would introduce an exchange rate risk exposure for which Microsoft would want to be compensated in the form of higher prices on its software. Consequently, the foreign exports of Microsoft are typically transacted in U.S. dollars and are therefore tied inextricably to the price of the dollar against other currencies. As the value of the dollar rises, offshore buyers must pay a larger amount of their own currency to obtain the U.S. dollars required to complete a purchase order for Microsoft's software, and this decreases the export demand. Even in a large domestic market like the United States, companies often find that these export demand considerations are key determinants of their overall demand.

Example

Exchange Rate Impacts on Demand: Cummins Engine Company

Cummins Engine Company of Columbus, Indiana, is the largest independent manufacturer of new and replacement diesel engines for heavy trucks and for construction, mining, and agricultural machinery. Volvo and Daimler-Benz are their major competitors, and 53 percent of sales occur offshore. The Cummins and Daimler-Benz large diesel truck engines sell for approximately \$40,000 and €35,000, respectively. In the 2002 recession, Cummins *suffered* substantial declines in cash flow. One reason was obvious: diesel replacement engines are not needed when fewer goods are being delivered, and therefore fewer diesels are wearing out.

In addition, however, between 1999 and 2002, the value of the U.S. dollar (€ per \$) increased by 30 percent from €0.85/\$ to €1.12/\$. This meant that a \$40,000 Cummins diesel engine that had sold for €34,000 in Munich in 1999 became €44,800, whereas the €35,000 Mercedes diesel alternative that had been selling for \$41,176 in Detroit declined to \$31,250 because of the stronger U.S. dollar. Cummins faced two unattractive options, either of which would reduce its cash flow. It could either cut its profit margins and maintain unit sales, or maintain margins but have both offshore and

(Continued)

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domestic sales collapse. The company chose to cut margins and maintain sales. By 2005, the dollar's value had eroded, returning to €.85/\$, and Cummins' sales performance markedly improved. In the interim, demand for Cummins engines was adversely affected by the temporary appreciation of the U.S. dollar.

In 2009, with the U.S. dollar at a still lower value of €.64/\$, the Cummins Engine Co. could barely keep up with export demand since diesels to Europe were priced at €25,600 versus Mercedes, €32,000. Similarly, in Cleveland, St. Louis, and Atlanta, Cummins \$40,000 diesels were up against \$54,688 Mercedes substitutes. What a great time to be an American company competing against European manufacturers.

Individual and Market Supply Curves

What determines the planned rate of sale Q_s/t ? Like the demand schedule, the supply schedule is a list of prices and corresponding quantities that an individual or group of sellers desires to sell at uniform prices, *holding constant the influence of all other factors*. A number of these other determinants of supply that management will often need to consider are detailed in Table 2.3. The **supply function** can be represented as

$$Q_s = f(P, P_I, P_{UI}, T, EE, F, RC, P_E, T/S \dots) \quad [2.2]$$

where Q_s = quantity supplied (e.g., of domestic autos)

P = price of the autos

P_I = price of inputs (e.g., sheet metal)

P_{UI} = price of unused substitute inputs (e.g., fiberglass)

T = technological improvements (e.g., robotic welding)

EE = entry or exit of other auto sellers

F = accidental supply interruptions from fires, floods, etc.

RC = costs of regulatory compliance

P_E = expected (future) changes in price

T_A = adjustment time period

T/S = taxes or subsidies

supply function

A relationship between quantity supplied and all the determinants of supply.

TABLE 2.3 PARTIAL LIST OF FACTORS AFFECTING SUPPLY

SUPPLY FACTOR	EXPECTED EFFECT AT EVERY PRICE
Increase (decrease) in the price of inputs (P_I)	Decrease (increase) in supply
Increase (decrease) in the price of unused substitute inputs (P_{UI})	Decrease (increase) in supply
Technological improvements (T)	Increase in supply
Entry (Exit) of other sellers (EE)	Increase (decrease) in supply
Supply disruptions (F)	Decrease in supply
Increase (decrease) in regulatory costs (RC)	Decrease (increase) in supply
Expected future price increases (decreases) (P_E)	Decrease (increase) in supply
Time period of adjustment lengthens (shortens) (T_A)	Increase (decrease) in supply
Taxes (subsidies) (T/S)	Decrease (increase) in supply

Example**NAFTA and the Reduced Labor Costs of Ford Assembly Plants in Detroit**

The North American Free Trade Agreement (NAFTA) made it possible to buy subassemblies like axles and engine blocks from Mexican suppliers like Cifunsa, SA, without paying any import tariff when the parts arrived in the United States. Since United Auto Worker (UAW) labor in Detroit auto assembly plants also makes axle subassemblies, the Mexican labor input can be thought about as an unused substitute input from the point of view of Ford Motor Company. NAFTA in effect lowered the input cost of substitute inputs for Ford. This means fewer employers would pursue labor contracts with UAW labor in Detroit and instead shift some of their production south across the Mexican border. Less demand implies lower equilibrium wages would be offered and accepted by UAW assembly line labor. Hence, the indirect effect of NAFTA was a reduction in the input costs for UAW labor that the Ford Motor Co. did utilize. As usual, lower input cost implies a shift of the supply curve down and to the right, an increase in supply.

supply curve

A relationship between price and quantity supplied, holding other determinants of supply constant.

Again, changes in the price (P) of the good or service will result only in movement along the given **supply curve**, whereas changes in any of the other independent variables (P_S , P_C , Y , A , A_C , N , C_P , P_E , and so on) in the function shift the supply curve. As with demand, a movement *along* a supply curve is referred to as *a change in the quantity supplied*, while holding constant other determinants of supply. A shift of the entire supply curve is often referred to as *a change in supply* and is always caused by some supply determinant other than price.

Equilibrium Market Price of Gasoline

In April–July 2008, Americans woke up to a new reality about gasoline that markedly affected their driving habits as well as U.S. public policy. The price of a gallon of regular octane gasoline skyrocketed from \$3.00 per gallon to \$4.10 (see Figure 2.4). The previous summer, when gas prices had hovered around \$3 per gallon, Americans had cut back only slightly on non-essential driving.

In the summer of 2008, with regular gasoline at \$4.10 per gallon, not only summer driving vacations but urban commuting itself changed in extraordinary ways. Overall, customer demand by the typical two-person urban household shrank from 16 gallons per week to 11.5 gallons. As a result, for the first time in U.S. history, gasoline expenditure by U.S. households declined despite a rising price at the pump—that is, 16 gallons/week at \$3 in 2007 (Q3) = \$48 > 11.5 gallons per week at \$4.10 in 2008 (Q3) = \$47.15.

Several determinants of demand and supply were identified as possible explanations for the spike in gasoline's equilibrium market price. First, much was written about the fact that no new refinery had been built in the United States in more than 30 years, suggesting that refinery capacity shortages or pipeline bottlenecks might be responsible. Declining capacity does shift the supply curve in Figure 2.2 to the left, which would imply a higher equilibrium price. But no refinery closings or pipeline disruptions could be identified that summer. And the U.S. Department of Energy found refineries command only \$0.36 per gallon of the final product price of gasoline for cost recovery plus profit and

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FIGURE 2.4 Average Gas Prices in the United States



Source: AAA Carolinas.

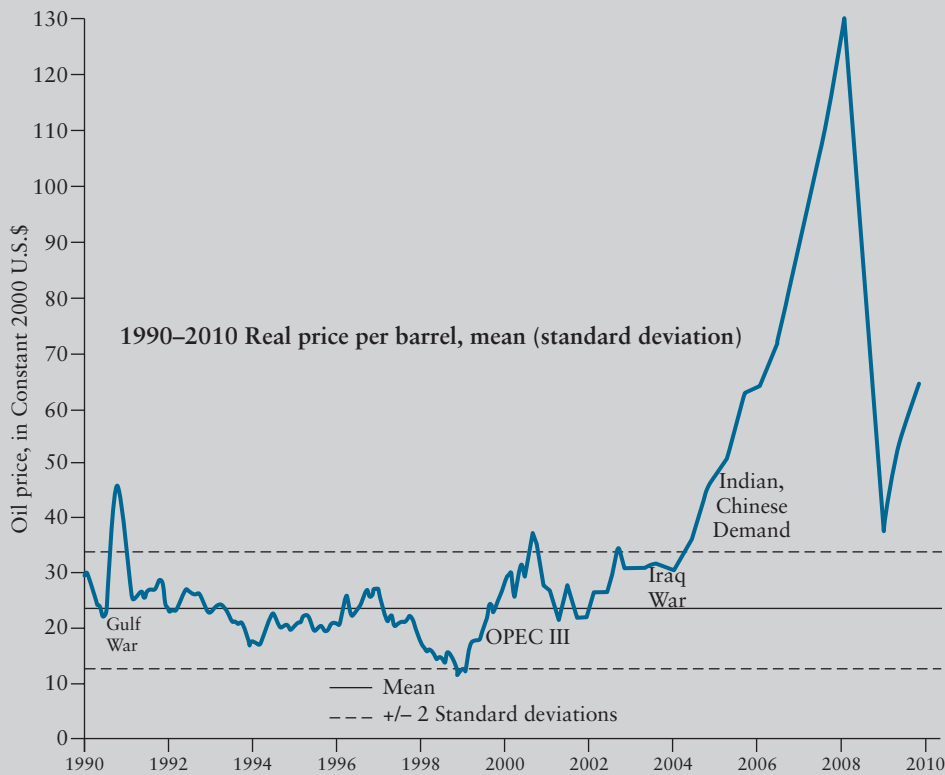
could not therefore be responsible for the \$1.10 increase in the equilibrium price between July 2007 and July 2008.

Second, retail gas station owners were accused of gouging the driving public. Higher markups at retail also would shift the supply curve for gasoline back to the left, raising the equilibrium market price. But again, retail markup and indeed all gasoline marketing were found to add only \$0.28 per gallon to the \$4.10 price, much less than could be responsible for the \$1.10 run-up in gasoline’s equilibrium market price. Third, excise taxes on gasoline (earmarked for road building and maintenance) are levied by both the federal and state governments. Gasoline taxes constitute \$0.41 per gallon on average across the United States. Any new excise taxes would have shifted the supply curve leftward, resulting in a higher equilibrium market price for gasoline. President George Bush’s Council of Economic Advisors in 2007 did explore levying an additional \$1 per gallon tax on gasoline to reduce the dependence of the United States on foreign oil, but no tax increase was ever initiated. So what was responsible for the upward spike in gasoline prices?

As we have seen, the variables in the demand and supply functions in Equations 2.1 and 2.2 determining equilibrium market price may be grouped into three broad sets of factors affecting use value, cost of production, and resource scarcity.² Since crude oil inputs account for \$2.96 of the \$4.10 final product price of gasoline, resource scarcity was a likely candidate to explain the increase in gasoline prices from \$3 to \$4.10. Higher crude oil input prices shift the supply curve leftward, leading to higher final product prices for gasoline. Figure 2.5 shows that the previous three times crude oil input prices shot up, supply disruptions in the crude oil input market were involved (i.e., during the first Gulf War in Kuwait in 1991, during an especially effective era for the OPEC cartel 1999–2001, and during the Iraq War in 2004).

In contrast, the crude oil input price rise from \$40 to \$80 per barrel in 2006–2007 reflected demand-side increased usage especially by India and China. India and China are only 9 percent of the 85 million barrels per day (mbd) worldwide crude oil market but these two countries have been growing very quickly. A 2 to 3 percent additional

²Two additional factors are speculation and government intervention in the form of taxes, subsidies, and regulations.

FIGURE 2.5 Supply Disruptions and Developing Country Demand Fuel Crude Oil Price Spikes

Source: Federal Reserve Bank, St. Louis, *National Economics Trends* (September 2000); FedDallas, Regional Economic Data, 2006.

demand can significantly raise equilibrium prices for crude oil resources because at any point in time there is a very thin inventory (8–10 days supply) working its way through the distribution network from wells to pumps to terminals to tankers to refineries. By late 2007, crude oil input prices were rising beyond \$80 per barrel. As gasoline headed toward \$4.10 per gallon in the United States, \$9.16 per gallon in Germany, and \$8.80 per gallon in Great Britain, Western drivers substantially cut back consumption. Brazil approached \$6.40 per gallon and pursued a successful energy independence campaign focused on sugar cane-based ethanol plants.

Was the \$80 price in late 2007 the highest price ever in the crude oil input market prior to that time? The answer is “no.” In 1981, the equilibrium crude oil price reached \$36 per barrel. Using the U.S. consumer price index (CPI), since crude oil transactions worldwide are denominated in U.S. dollars, cumulative price increases between 1981 and 2007 total 228.8 percent, so $\$36 \times 2.288$ inflation-adjustment multiplier equals \$82 in 2007, and $\$80/2.288$ equals \$35 in 1981. Consequently, the \$80 crude oil price in late 2007 was in fact lower than the inflation-adjusted \$36 crude price in 1981 at the height of the influence of the OPEC II oil cartel. However, in early 2008, the equilibrium price of crude continued to spike upward.

When the crude price climbed above \$100, large numbers of speculators acquired long positions in the crude oil futures market betting on a further price rise. Speculative

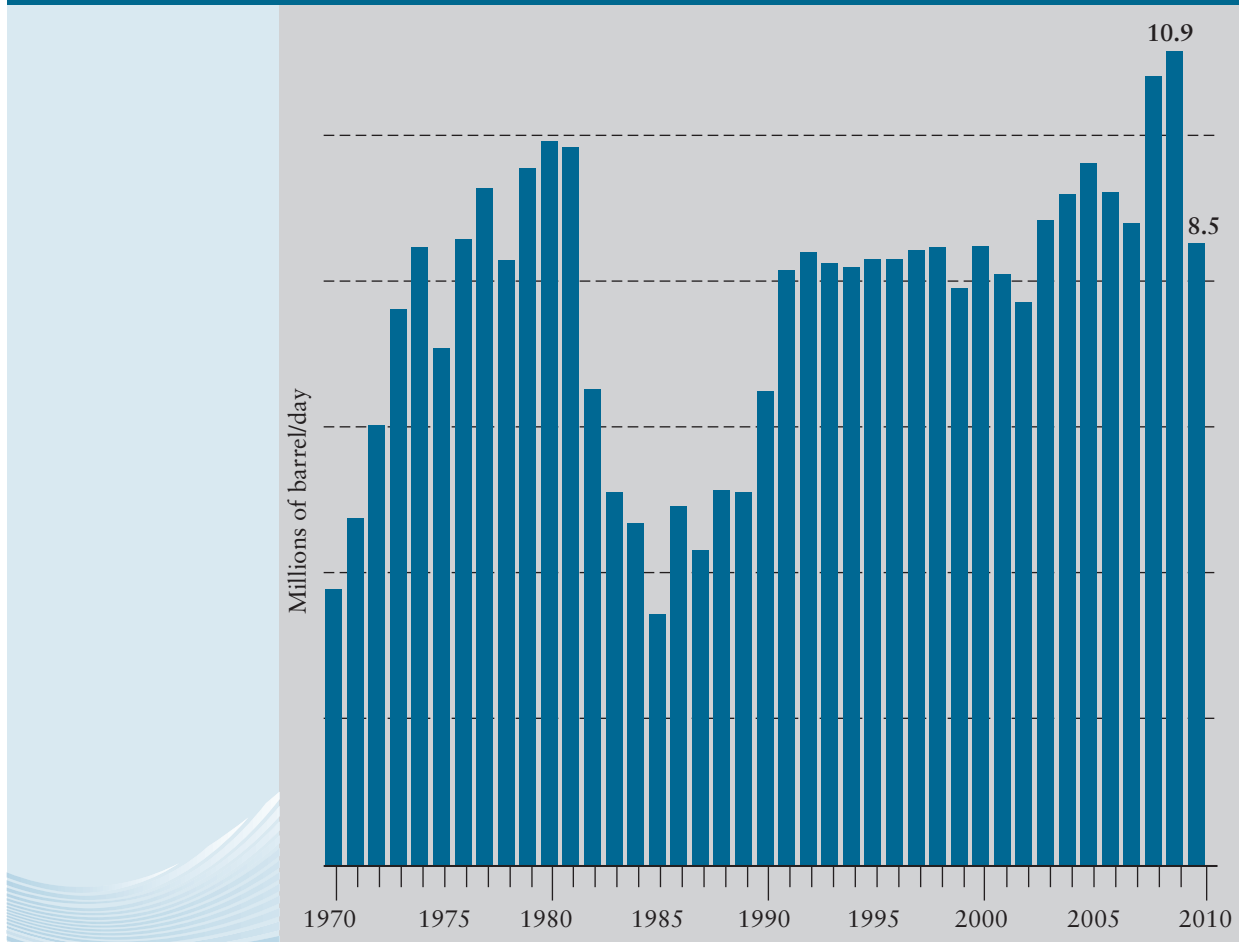
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demand (supply) is always motivated by the anticipation of equilibrium market prices being higher (lower) tomorrow. Those who “go long” and buy futures contracts to take delivery at prices agreed on today are betting the price will go up, and those who “sell short” and write futures contracts promising to deliver in the future at prices agreed on today are betting the other way. The net long direction of speculative trading in the first half of 2008 added to the growing market demand from India and China and drove the crude oil equilibrium price still higher, eventually reaching \$146 per barrel in July 2008.

Faced with \$4.10 per gallon gasoline, as ExxonMobil and Shell sought to recover their extraordinary input costs for crude, American consumers decided to vacate their SUVs, join carpools, and ride the buses and trains to work. Urban mass transit system ridership shot up 20 percent in a matter of months. Other Americans purchased fuel-efficient hybrids like the Toyota Prius. Still others mobilized behind T. Boone Pickens’s plan to convert the federal trucking fleet to natural gas. Fearing an onslaught of feasible substitutes like hybrid electric cars and natural gas-powered trucks, the Saudis ramped up crude oil production from their average 8.5 mbd 1990–2006 all the way to 10.5 and 10.9 mbd in 2007 and 2008 (see Figure 2.6).



FIGURE 2.6 Saudi Arabia Crude Oil Production



Source: U.S. Energy Information Administration.

With U.S. demand for gasoline declining and capacity to extract and refine expanding, the equilibrium price of crude finally turned and began to decline. The late 2008 crude oil price reversal was caused by a combination of increasing supply fundamentals (shifting the supply curve to the right), slowing demand growth, and a speculative expectation that in the near term crude prices would be lower (not higher). Consequently, the supply of crude oil (and especially of highly leveraged crude oil futures contracts) mushroomed. Angola doubled production capacity to 2.1 mbd, and Saudi capacity grew to 12.5 mbd. Saudi Arabia and Kuwait also broke ground on two giant new refining facilities.

Example

Speculation Sends Crude Oil Input Price on a Roller-Coaster Ride at ExxonMobil and Shell

With reversed expectations of lower crude prices in the near term, the speculative bubble in crude oil quickly burst. Despite 5 percent *higher* market demand over the last four months of 2008 (again primarily from China and India), the equilibrium price of crude oil plummeted more than \$100 a barrel from \$146 in September 2008 to a low of \$40 by January 2009 (see Figure 2.7). By 2009 (Q3), the crude price stood again at \$75 per barrel, and gasoline was selling for \$2.74 per gallon. Although North American import demand for crude oil has been flat in recent years, OPEC members clearly believe that the spectacular 22 percent demand growth from Asian developing countries in 2000–2008 will continue. Over a two-year period, rising Asian demand, massive capacity expansions, a worldwide financial boom, then collapse, and speculative buying followed by speculative selling had taken oil companies and gasoline buyers on quite a roller-coaster ride.

FIGURE 2.7 Crude Oil Price, West Texas Intermediate



Source: Thomson Datasteam.

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marginal analysis

A basis for making various economic decisions that analyzes the additional (marginal) benefits derived from a particular decision and compares them with the additional (marginal) costs incurred.

MARGINAL ANALYSIS

Marginal analysis is one of the most useful concepts in microeconomics. Resource-allocation decisions typically are expressed in terms of the marginal equilibrium conditions that must be satisfied to attain an optimal solution. The familiar profit-maximization rule for the firm of setting output at the point where “marginal cost equals marginal revenue” is one such example. Long-term investment decisions (capital expenditures) also are made using marginal analysis decision rules. Only if the expected return from an investment project (that is, the *marginal return* to the firm) exceeds the cost of funds that must be acquired to finance the project (the *marginal cost* of capital), should the project be undertaken. Following this important marginal decision rule leads to the maximization of shareholder wealth.

Example

Tenneco Shipyard Marginal Analysis

Resource-allocation decisions should be made by comparing the marginal (or incremental) benefits of a change in the level of an activity with the incremental costs of the change. For example, the marginal revenue benefit derived from producing and selling one more supertanker is equal to the difference between total revenue, assuming the additional unit is not sold, and total revenue including the additional sale. Similarly, *marginal cost* is defined as the change in total costs that occurs from undertaking some economic activity, such as the production of an additional ship design including the opportunity costs, and therefore may not necessarily always be equal to the cash outlays alone. Perhaps the Tenneco design team has an opportunity for higher net profit as subcontractors on Boeing projects. If so, Tenneco’s routine ship-design work should be contracted out to other ship building design firms who can become a trusted subcontractor to Tenneco.

More generally, a change in the level of an economic activity is desirable if the marginal benefits exceed the marginal (that is, the incremental) costs. If we define *net marginal return* as the *difference* between marginal benefits and marginal costs, then an equivalent optimality condition is that the level of the activity should be increased to the point where the net marginal return is zero.

In summary, marginal analysis instructs decision makers to determine the additional (marginal) costs and additional (marginal) benefits associated with a proposed action. *Only if the marginal benefits exceed the marginal costs* (that is, if net marginal benefits are positive) should the action be taken.

Total, Marginal, and Average Relationships

Revenue, cost, profit, and many other economic relationships can be presented using tabular, graphic, and algebraic frameworks. Let us first use a tabular presentation. Suppose

Example**Marginal Analysis and Capital Budgeting Decisions:
Sara Lee Corporation**

The capital budgeting decision problem facing a typical firm, such as Sara Lee Corporation, can be used to illustrate the application of marginal analysis decision rules. Sara Lee has the following schedule of potential investment projects (all assumed to be of equal risk) available to it:

PROJECT	INVESTMENT REQUIRED (\$ MILLION)	EXPECTED RATE OF RETURN	CUMULATIVE INVESTMENT (\$ MILLION)
A	\$25.0	27.0%	\$ 25.0
B	15.0	24.0	40.0
C	40.0	21.0	80.0
D	35.0	18.0	115.0
E	12.0	15.0	127.0
F	20.0	14.0	147.0
G	18.0	13.0	165.0
H	13.0	11.0	178.0
I	7.0	8.0	185.0

Sara Lee has estimated the cost of acquiring the funds needed to finance these investment projects as follows:

BLOCK OF FUNDS (\$ MILLION)	COST OF CAPITAL	CUMULATIVE FUNDS RAISED (\$ MILLION)
First \$50.0	10.0%	\$ 50.0
Next 25.0	10.5	75.0
Next 40.0	11.0	115.0
Next 50.0	12.2	165.0
Next 20.0	14.5	185.0

The expected rate of return on the projects listed above can be thought of as the marginal (or incremental) return available to Sara Lee as it undertakes each additional investment project. Similarly, the cost-of-capital schedule may be thought of as the incremental cost of acquiring the needed funds. Following the marginal analysis rules means that Sara Lee should invest in additional projects as long as the expected rate of return on the project exceeds the marginal cost of capital funds needed to finance the project.

Project A, which offers an expected return of 27 percent and requires an outlay of \$25 million, is acceptable because the marginal return exceeds the marginal cost of capital (10.0 percent for the first \$50 million of funds raised by Sara Lee). In fact, an examination of the tables indicates that projects A through G all meet the marginal analysis test because the marginal return from each of these projects exceeds the marginal cost of capital funds needed to finance these projects. In contrast, projects H and I should not be undertaken because they offer returns of 11 percent and 8 percent, respectively, compared with a marginal cost of capital of 14.5 percent for the \$20 million in funds needed to finance those projects.

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Example

Marginal Analysis of Driving a Mini Cooper versus a Chevy Volt



Urban sprawl and flight to the suburbs have now resulted in the mean commuter trip in the United States rising to 33 miles one way. With the housing density in most American cities well below what would be required to support extensive light rail and subway lines, the typical household must find economical ways to get at least one worker from a suburban home to the central business district and back each day. A fuel-efficient, small commuter car like the Mini Cooper is one alternative. Others have recently been proposed—the Chevy Volt and Nissan Leaf, both all-electric vehicles that are recharged at the end of each 40-mile commuting trip. Technically, the Leaf and the Volt are e-REVs, extended-range electric vehicles. Each contains a small gasoline-driven internal combustion engine that runs an electric generator, but unlike hybrids such as the Ford Fusion and Toyota Prius, these e-REVs have no mechanical connection between the gasoline engine and the drivetrain. Instead, the Chevy Volt goes 40 miles on the charge contained in 220 lithium ion (L-ion) batteries which are plugged in for a recharging cycle of 8 hours at 220 volts (or 3 hours at 110 volts) at work and at home. When the battery pack falls to a 30 percent state of charge (SOC), the gasoline engine comes on to turn the generator and maintain battery power above 25 percent SOC.

Automotive engineers calculate that each mile traveled in the Chevy Volt’s all-electric mode “burns” 0.26 kilowatt hours of electricity. So, the mean commuter trip of 33 miles requires 8.58 kWh of electricity. The price of electricity in the United States varies from a peak period in the afternoon and evening to a much cheaper off-peak period late at night, and from a low of \$0.07 per kWh in Washington state to \$0.12 in Rhode Island. On average, a representative nighttime rate is \$0.10, and a representative daytime rate is \$0.13. This means that each nighttime charge will run the household \$0.86, and the comparable daytime charge downtown at work will be \$1.12 for a total operating cost per day of just under \$2. For 300 days of work, that’s \$600 per year. In contrast, the gasoline-powered Mini Cooper gets 32 mpg, so at \$3.00 per gallon, the Mini’s operating cost is approximately \$6 per day or \$1,800 per year. The typical commuter use of e-Rev vehicles will save \$4 per day or \$1,200 per year relative to popular fuel-efficient gasoline-powered cars.

At an EPA-measured 41 mpg throughout a range of driving conditions, the hybrid-electric Ford Fusion qualifies for a federal tax credit of \$3,400. In contrast, at an EPA-measured 238 mpg, the Chevy Volt qualifies for a \$7,500 tax credit to offset the \$12,000 additional cost of the L-ion battery pack over the cost of a conventional battery. Because the Chevy Volt’s battery pack is expected to last 10 years, the \$1,200 annual capital cost for the battery pack is equal to the \$1,200 energy cost savings even without the federal tax credit.

that the total profit π_T of a firm is a function of the number of units of output produced Q , as shown in columns 1 and 2 of Table 2.4.

Marginal profit, which represents the change in total profit resulting from a one-unit increase in output, is shown in column 3 of the table. (A Δ is used to represent a “change” in some variable.) The marginal profit $\Delta\pi(Q)$ of any level of output Q is calculated by taking the difference between the total profit at this level $\pi_T(Q)$ and at one unit below this level $\pi_T(Q - 1)$.³ In comparing the marginal and total profit functions, we

³Web Appendix A expands upon the idea that the total profit function can be maximized by identifying the level of activity at which the marginal profit function goes to zero.

TABLE 2.4 TOTAL, MARGINAL, AND AVERAGE PROFIT RELATIONSHIPS

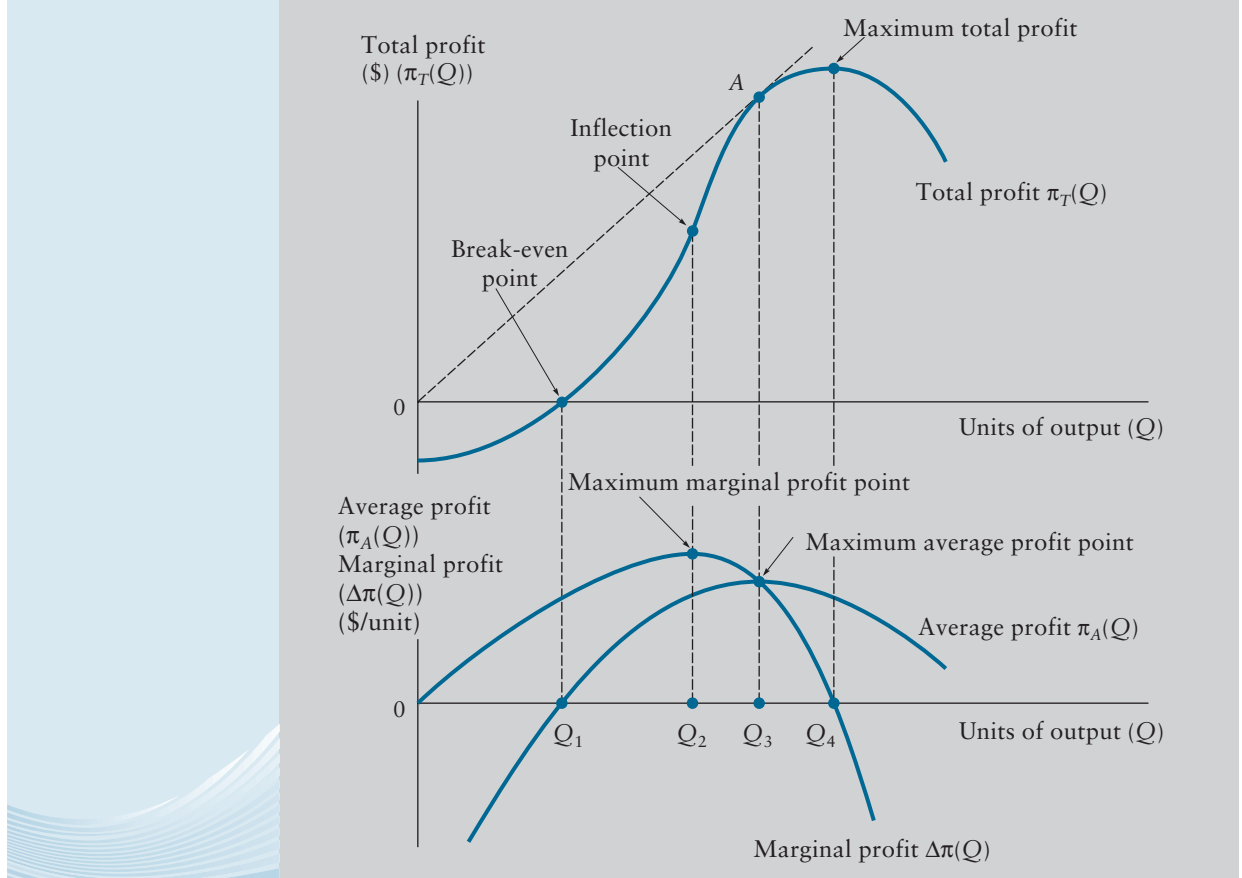
(1)	(2)	(3)	(4)
NUMBER OF UNITS OF OUTPUT PER UNIT OF TIME Q	TOTAL PROFIT $\pi_T(Q)$ (\$)	MARGINAL PROFIT $\Delta\pi(Q) = \pi_T(Q) - \pi_T(Q - 1)$ (\$/UNIT)	AVERAGE PROFIT $\pi_A(Q) = \pi_T(Q)/Q$ (\$/UNIT)
0	-200	0	—
1	-150	50	-150.00
2	-25	125	-12.50
3	200	225	66.67
4	475	275	118.75
5	775	300	155.00
6	1,075	300	179.17
7	1,325	250	189.29
8	1,475	150	184.38
9	1,500	25	166.67
10	1,350	-150	135.00

note that for increasing output levels, the marginal profit values remain positive as long as the total profit function is increasing. Only when the total profit function begins decreasing—that is, at $Q = 10$ units—does the marginal profit become negative. The average profit function values $\pi_A(Q)$, shown in column 4 of Table 2.4, are obtained by dividing the total profit figure $\pi_T(Q)$ by the output level Q . In comparing the marginal and the average profit function values, we see that the average profit function $\pi_A(Q)$ is increasing as long as the marginal profit is greater than the average profit—that is, up to $Q = 7$ units. Beyond an output level of $Q = 7$ units, the marginal profit is less than the average profit and the average profit function values are decreasing.

By examining the total profit function $\pi_T(Q)$ in Table 2.4, we see that profit is maximized at an output level of $Q = 9$ units. Given that the objective is to maximize total profit, then the optimal output decision would be to produce and sell 9 units. If the marginal analysis decision rule discussed earlier in this section is used, the same (optimal) decision is obtained. Applying the rule to this problem, the firm would expand production as long as the *net* marginal return—that is, marginal revenue minus marginal cost (marginal profit)—is positive. From column 3 of Table 2.4, we can see that the marginal profit is positive for output levels up to $Q = 9$. Therefore, the marginal profit decision rule would indicate that 9 units should be produced—the same decision that was obtained from the total profit function.

The relationships among the total, marginal, and average profit functions and the optimal output decision also can be represented graphically. A set of *continuous* profit functions, analogous to those presented in Table 2.4 for discrete integer values of output (Q), is shown in Figure 2.8. At the break-even output level Q_1 , both total profits and average profits are zero. The marginal profit function, which equals the *slope* of the total profit function, takes on its maximum value at an output of Q_2 units. This point corresponds to the *inflection point*. Below the inflection point, total profits are increasing at an increasing rate, and hence marginal profits are increasing. Above the inflection point, up to an output level Q_4 , total profits are increasing at a decreasing rate, and consequently marginal profits are decreasing. The average profit function, which represents the slope of a straight line drawn from the origin 0 to each point on

FIGURE 2.8 Total, Average, and Marginal Profit Functions



the total profit function, takes on its maximum value at an output of Q_3 units. The average profit necessarily equals the marginal profit at this point. This follows because the slope of the $0A$ line, which defines the average profit, is also equal to the slope of the total profit function at point A , which defines the marginal profit. Finally, total profit is maximized at an output of Q_4 units where marginal profit equals 0. Beyond Q_4 the total profit function is decreasing, and consequently the marginal profit function takes on negative values.

THE NET PRESENT VALUE CONCEPT

When costs and benefits occur at approximately the same time, the marginal decision rule (proceed with the action if marginal benefit exceeds marginal cost) applies. But, many economic decisions require that costs be incurred immediately to capture a stream of benefits over several future time periods. In these cases, the *net present value* (NPV) rule replaces the marginal decision rule and provides appropriate guidance for longer-term decision makers. The NPV of an investment represents the contribution of that investment to the value of the firm and, accordingly, to shareholder wealth maximization.

Determining the Net Present Value of an Investment

To understand the NPV rule, consider the following situation. You are responsible for investing \$1 million to support the retirement of several family members. Your financial advisor has suggested that you use these funds to purchase a piece of land near a proposed new highway interchange. A trustworthy state road commissioner is certain that the interchange will be built and that in one year the value of this land will increase to \$1.2 million. Hence, you believe initially that this is a riskless investment. At the end of one year you plan to sell the land. You are being asked to invest \$1 million today in the anticipation of receiving \$1.2 million a year from today, or a profit of \$200,000. You wonder whether this profit represents a sufficient return on your investment.

You feel it is important to recognize that a return of \$1.2 million received one year from today must be worth less than \$1.2 million today because you could invest your \$1 million today to earn interest over the coming year. Therefore, to compare a dollar received in the future with a dollar in hand today, it is necessary to multiply the future dollar by a *discount factor* that reflects the alternative investment opportunities that are available.

Instead of investing \$1 million in the land venture, you are aware that you could also invest in a one-year U.S. government bond that currently offers a return of 3 percent. The 3 percent return represents the return (the opportunity cost) forgone by investing in the land project. The 3 percent rate also can be thought of as the compensation to an investor who agrees to postpone receiving a cash return for one year. The discount factor, also called a *present value interest factor (PVIF)*, is equal to

$$PVIF = \frac{1}{1 + i}$$

where i is the compensation for postponing receipt of a cash return for one year. The **present value** (PV_0) of an amount received one year in the future (FV_1) is equal to that amount times the discount factor, or

$$PV_0 = FV_1 \times (PVIF) \quad [2.3]$$

In the case of the land project, the present value of the promised \$1.2 million expected to be received in one year is equal to

$$PV_0 = \$1.2 \text{ million} \left(\frac{1}{1 + 0.05} \right) = \$1,142,857$$

If you invested \$1,165,049 today to earn 3 percent for the coming year, you would have \$1.2 million at the end of the year. You are clearly better off with the proposed land investment (assuming that it really is riskless like the U.S. government bond investment). How much better off are you?

The answer to this question is at the heart of NPV calculations. The land investment project is worth \$1,165,049 today to an investor who demands a 3 percent return on this type of investment. You, however, have been able to acquire this investment for only \$1,000,000. Thus, your wealth has increased by undertaking this investment by \$165,049 (\$1,165,049 present value of the projected investment opportunity payoffs minus the required initial investment of \$1,000,000). The NPV of this investment is \$165,049. In general, the NPV of an investment is equal to

$$NPV = \text{Present value of future returns} - \text{Initial outlay} \quad [2.4]$$

This example was simplified by assuming that the returns from the investment were received exactly one year from the date of the initial outlay. If the payoff from the land

present value The value today of a future amount of money or a series of future payments evaluated at the appropriate discount rate.

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Example

Changing a Lightbulb Saves \$40 and May Save the Planet⁴

Incandescent lightbulbs replaced oil lamps for interior lighting more than 100 years ago. Thomas Edison himself improved on some basic designs running electric current through a carbonized filament in an oxygen-free vacuum tube, producing less combustion and more light. General Electric had its origins selling long-lasting tungsten filament incandescent bulbs. Today, the new compact fluorescent light (CFL) bulb uses 75 percent less electricity to heat an argon vapor that emits ultraviolet light. The UV light excites a fluorescent phosphor coating on the inside of the tube, which then emits visible light. The U.S. Department of Energy estimates that if all 105 million U.S. households replaced just one heavily used incandescent bulb with a CFL bulb yielding comparable light, the electricity saved could light 3 million homes. In addition, the energy saved would remove from the environment an amount of greenhouse gases from coal-burning power plants equal to the CO₂ emitted by 800,000 cars. The U.K. Department of Business, Enterprise, and Regulatory Reform estimates that replacing the three most frequently used lightbulbs in U.K. households would save the electricity used by all the street lamps in Britain.

The magnitude of these energy savings is certainly staggering, but at what cost? Bought for \$1.19 per bulb, 1,000-hour incandescent 75-watt bulbs cost much less to install than CFL bulbs that create the same 1,250 lumens of light, last 8,000 hours, burn only 18 to 22 watts of electricity, but cost \$14. So, the lifetime cost comparison hinges on whether the extra \$12.81 acquisition cost of the CFL bulb is worth the extended lifetime of energy savings. Net present value techniques are designed to answer just such questions of the time value of money (savings) that are delayed.

Table 2.5 shows the initial net investments of \$14 and \$1.19 per bulb, the 55 kilowatt hours (kWh) of power saved on average by the CFL bulb each year, the \$0.10 per kWh representative cost of the electricity,⁵ and the additional \$1.19 incandescent bulb replacement every 1,000 hours (the typical U.S. household's annual usage). Assuming a 6 percent discount rate, the net present value of the \$5.50 annual energy savings plus the \$1.19 replacement cost for incandescent bulbs avoided each year for seven years yields a net present value cost savings of \$40.79, which exceeds the differential \$12.81 acquisition cost for the CFL bulb by \$27.98. The European Union has found this \$28 net present value of the cost savings from switching to CFL bulbs (plus their CO₂ abatement) so compelling that incandescent bulbs are no longer approved for manufacture or import into the EU. More gradual U.S. phaseout of incandescent bulbs will begin in 2012.

⁴Based on "DOE Launches Change a Light, Change the World Campaign" (October 3, 2007), www.energy.gov and www.energystar.gov.

⁵Electric rates for incremental power vary by region from \$0.06 per kWh in the state of Washington to \$0.08 in the Carolinas, to \$0.12 in California, New York, and across New England.

investment had been not one but two years away, the PVIF would have been $1/(1.03)^2 = 0.942596$, and the NPV would have been 1.2 million $(.942596) - 1.0$ million = \$131,115. The NPV rule can be generalized to cover returns received over any number of future time periods with projected growth or decay and terminal values as salvage or disposal costs. In Appendix A at the end of the book, the present value concept is developed in more detail so that it can be applied in these more complex investment settings.

TABLE 2.5 LIFETIME COST SAVINGS OF COMPACT FLUORESCENT LIGHT (CFL) BULBS

	t=0	t=1	t=2	t=3	t=4	t=5	t=6	t=7	t=8
									(END OF PERIOD VALUES)
Incandescent	-\$1.19	-\$1.19	-\$1.19	-\$1.19	-\$1.19	-\$1.19	-\$1.19	-\$1.19	0
CFL	-\$14.00	55 kWh × \$.10 = \$5.50	\$5.50	\$5.50	\$5.50	\$5.50	\$5.50	\$5.50	\$5.50
Cost difference	-\$12.81		NPV (8 years of \$5.5 energy savings at d=6%) = \$34.15						
			NPV (7 years of \$1.19 incandescent replacement cost at d=6%) = \$6.64						
			NPV (Lifetime cost savings) – Cost difference						
			(\$34.15 + \$6.64) \$40.79		\$12.81				
			= \$27.98						

Sources of Positive Net Present Value Projects

What causes some projects to have a positive NPV and others to have a negative NPV? When product and factor markets are other than perfectly competitive, it is possible for a firm to earn above-normal profits (economic rents) that result in positive net present value projects. The reasons why these above-normal profits may be available arise from conditions that define each type of product and factor market and distinguish it from a perfectly competitive market. These reasons include the following barriers to entry and other factors:

1. Buyer preferences for established brand names
2. Ownership or control of favored distribution systems (such as exclusive auto dealerships or airline hubs)
3. Patent control of superior product designs or production techniques
4. Exclusive ownership of superior natural resource deposits
5. Inability of new firms to acquire necessary factors of production (management, labor, equipment)
6. Superior access to financial resources at lower costs (economies of scale in attracting capital)
7. Economies of large-scale production and distribution arising from
 - a. Capital-intensive production processes
 - b. High initial start-up costs

These factors can permit a firm to identify positive net present value projects for internal investment. If the barriers to entry are sufficiently high (such as a patent on key technology) so as to prevent any new competition, or if the start-up period for competitive ventures is sufficiently long, then it is possible that a project may have a positive net present value. However, in assessing the viability of such a project, the manager or analyst must consider the likely period of time when above-normal returns can be earned before new competitors emerge and force cash flows back to a more normal level. It is generally unrealistic to expect to be able to earn above-normal returns over the entire life of an investment project.

Risk and the NPV Rule

The previous land investment example assumed that the investment was riskless. Therefore, the rate of return used to compute the discount factor and the net present value was the riskless rate of return available on a U.S. government bond having a one-year maturity. What if you do not believe that the construction of the new interchange is a

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certainty, or you are not confident about the value of the land in one year? To compensate for the perceived risk of this investment, you decide that you require a 15 percent rate of return on your investment. Using a 15 percent required rate of return in calculating the discount factor, the present value of the expected \$1.2 million sales price of the land is \$1,043,478 (\$1.2 million times $[1/1.15]$). Thus, the NPV of this investment declines to \$43,478. The increase in the perceived risk of the investment results in a dramatic \$121,571 decline from \$165,049 in the NPV on a \$1 million investment.

A primary problem facing managers is the difficulty of evaluating the risk associated with investments and then translating that risk into a discount rate that reflects an adequate level of risk compensation. In the next section of this chapter, we discuss the risk concept and the factors that affect investment risk and influence the required rate of return on an investment.

MEANING AND MEASUREMENT OF RISK

risk A decision-making situation in which there is variability in the possible outcomes, and the probabilities of these outcomes can be specified by the decision maker.

Risk implies a chance for some unfavorable outcome to occur—for example, the *possibility that actual cash flows will be less than* the expected outcome. When a range of potential outcomes is associated with a decision and the decision maker is able to assign probabilities to each of these possible outcomes, risk is said to exist. A decision is said to be *risk free* if the cash flow outcomes are known with certainty. A good example of a risk-free investment is U.S. Treasury securities. There is virtually no chance that the Treasury will fail to redeem these securities at maturity or that the Treasury will default on any interest payments owed. In contrast, US Airways bonds constitute a *risky* investment because it is possible that US Airways will default on one or more interest payments and will lack sufficient funds at maturity to redeem the bonds at face value. In summary, *risk* refers to the potential variability of outcomes from a decision. The more variable these outcomes are, the greater the risk.

Probability Distributions

probability The percentage chance that a particular outcome will occur.

The **probability** that a particular outcome will occur is defined as the relative frequency or *percentage chance* of its occurrence. Probabilities may be either objectively or subjectively determined. An objective determination is based on past outcomes of similar events, whereas a subjective determination is merely an opinion made by an individual about the likelihood that a given event will occur. In the case of decisions that are frequently repeated, such as the drilling of developmental oil wells in an established oil field, reasonably good objective estimates can be made about the success of a new well. In contrast, for totally new decisions or one-of-a-kind investments, subjective estimates about the likelihood of various outcomes are necessary. The fact that many probability estimates in business are at least partially subjective does not diminish their usefulness.

Using either objective or subjective methods, the decision maker can develop a probability distribution for the possible outcomes. Table 2.6 shows the probability

INVESTMENT I		INVESTMENT II	
POSSIBLE NCF	PROBABILITY	POSSIBLE NCF	PROBABILITY
\$200	0.2	\$100	0.2
300	0.6	300	0.6
400	<u>0.2</u>	500	<u>0.2</u>
	1.0		1.0

distribution of net cash flows for two sample investments. The lowest estimated annual net cash flow (NCF) for each investment—\$200 for Investment I and \$100 for Investment II—represents pessimistic forecasts about the investments' performance; the middle values—\$300 and \$300—could be considered normal performance levels; and the highest values—\$400 and \$500—are optimistic estimates.

Example

Probability Distributions and Risk: US Airways Bonds

Consider an investor who is contemplating the purchase of US Airways bonds. That investor might assign the probabilities associated with the three possible outcomes from this investment, as shown in Table 2.7. These probabilities are interpreted to mean that a 30 percent chance exists that the bonds will not be in default over their life and will be redeemed at maturity, a 65 percent chance of interest default during the life of the bonds, and a 5 percent chance that the bonds will not be redeemed at maturity. In this example, no other outcomes are deemed possible.

TABLE 2.7 POSSIBLE OUTCOMES FROM INVESTING IN US AIRWAYS BONDS

OUTCOME	PROBABILITY
No default, bonds redeemed at maturity	0.30
Default on interest for one or more periods	0.65
No interest default, but bonds not redeemed at maturity	<u>0.05</u>
	1.00

Expected Values

From this information, the expected value of each decision alternative can be calculated. The **expected value** is defined as the weighted average of the possible outcomes. It is the value that is expected to occur on average if the decision (such as an investment) were repeated a large number of times.

Algebraically, the expected value may be defined as

$$\bar{r} = \sum_{j=1}^n r_j p_j \quad [2.5]$$

where \bar{r} is the expected value; r_j is the outcome for the j th case, where there are n possible outcomes; and p_j is the probability that the j th outcome will occur. The expected cash flows for Investments I and II are calculated in Table 2.8 using Equation 2.5. In this example, both investments have expected values of annual net cash flows equaling \$300.

TABLE 2.8 COMPUTATION OF THE EXPECTED RETURNS FROM TWO INVESTMENTS

INVESTMENT I			INVESTMENT II		
r_j	p_j	$r_j \times p_j$	r_j	p_j	$r_j \times p_j$
\$200	0.2	\$ 40	\$100	0.2	\$ 20
300	0.6	180	300	0.6	180
400	0.2	<u>80</u>	500	0.2	<u>100</u>
Expected value: $\bar{r}_I = \$300$			Expected value: $\bar{r}_{II} = \$300$		

expected value The weighted average of the possible outcomes where the weights are the probabilities of the respective outcomes.

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standard deviation

A statistical measure of the dispersion or variability of possible outcomes.

Standard Deviation: An Absolute Measure of Risk

The **standard deviation** is a statistical measure of the dispersion of a variable about its mean. It is defined as the square root of the weighted average squared deviations of individual outcomes from the mean:

$$\sigma = \sqrt{\sum_{j=1}^n (r_j - \bar{r})^2 p_j} \quad [2.6]$$

where σ is the standard deviation.

The standard deviation can be used to measure the variability of a decision alternative. As such, it gives an indication of the risk involved in the alternative. The larger the standard deviation, the more variable the possible outcomes and the riskier the decision alternative. A standard deviation of zero indicates no variability and thus no risk.

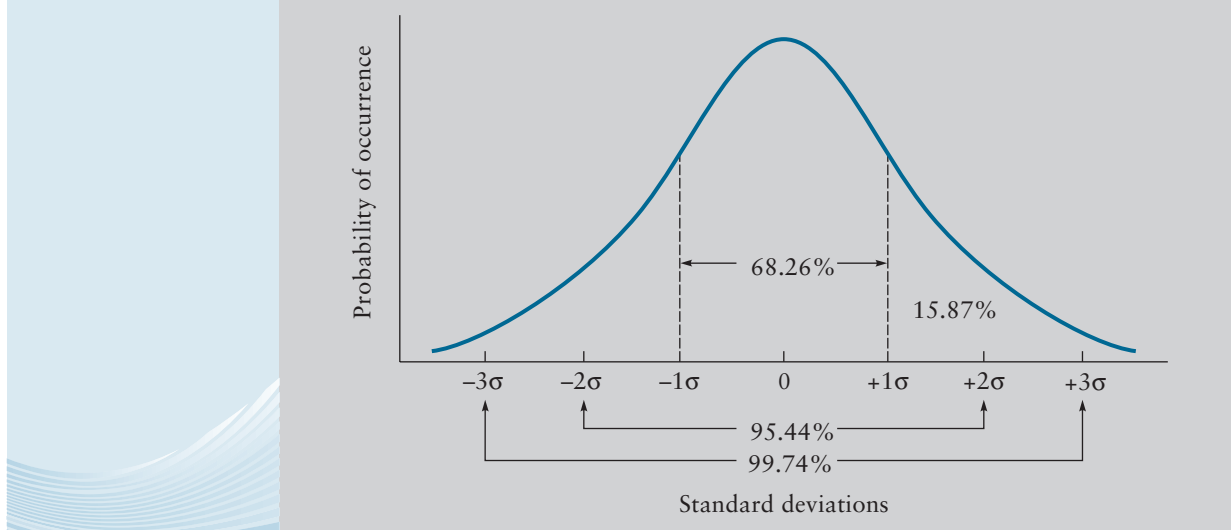
Table 2.9 shows the calculation of the standard deviations for Investments I and II. These calculations show that Investment II appears to be *riskier* than Investment I because the expected cash flows from Investment II are *more variable*.

Normal Probability Distribution

The possible outcomes from most investment decisions are much more numerous than in Table 2.6 but their effects can be estimated by assuming a continuous probability distribution. Assuming a *normal* probability distribution is often correct or nearly correct, and it greatly simplifies the analysis. The normal probability distribution is characterized by a symmetrical, bell-like curve. A table of the *standard normal probability function* (Table 1 in Appendix B at the end of this book) can be used to compute the probability of occurrence of any particular outcome. From this table, for example, it is apparent that the actual outcome should be between plus and minus 1

TABLE 2.9 COMPUTATION OF THE STANDARD DEVIATIONS FOR TWO INVESTMENTS

	j	r_j	\bar{r}	$r_j - \bar{r}$	$(r_j - \bar{r})^2$	p_j	$(r_j - \bar{r})^2 p_j$
Investment I	1	\$200	\$300	-\$100	\$10,000	0.2	\$2,000
	2	300	300	0	0	0.6	0
	3	400	300	100	10,000	0.2	<u>2,000</u>
						$\sum_{j=1}^3 (r_j - \bar{r})^2 p_j = \$4,000$	
		$\sigma = \sqrt{\sum_{j=1}^n (r_j - \bar{r})^2 p_j} = \sqrt{4,000} = \underline{\underline{\$63.25}}$					
Investment II	1	\$100	\$300	-\$200	\$40,000	0.2	\$8,000
	2	300	300	0	0	0.6	0
	3	500	300	200	40,000	0.2	<u>8,000</u>
						$\sum_{j=1}^3 (r_j - \bar{r})^2 p_j = \$16,000$	
		$\sigma = \sqrt{\sum_{j=1}^n (r_j - \bar{r})^2 p_j} = \sqrt{16,000} = \underline{\underline{\$126.49}}$					

FIGURE 2.9 A Sample Illustration of Areas under the Normal Probability Distribution Curve

standard deviation from the expected value 68.26 percent of the time,⁶ between plus and minus 2 standard deviations 95.44 percent of the time, and between plus and minus 3 standard deviations 99.74 percent of the time (see Figure 2.9). So a “3 sigma event” occurs less than 1 percent of the time with a relative frequency 0.0026 (i.e., $1.0 - 0.9974$), and a “9 sigma event” occurs almost never, with a relative frequency less than 0.0001. Nevertheless, such extraordinary events can and do happen (see following box on LTCM).

The number of standard deviations z that a particular value of r is from the mean \bar{r} can be computed as

$$z = \frac{r - \bar{r}}{\sigma} \quad [2.7]$$

Table 1 in Appendix B and Equation 2.5 can be used to compute the probability of an annual net cash flow for Investment I being less than some value r —for example, \$205. First, the number of standard deviations that \$205 is from the mean must be calculated. Substituting the mean and the standard deviation from Tables 2.8 and 2.9 into Equation 2.7 yields

$$\begin{aligned} z &= \frac{\$205 - \$300}{\$63.25} \\ &= -1.50 \end{aligned}$$

In other words, the annual cash flow value of \$205 is 1.5 standard deviations *below* the mean. Reading from the 1.5 row in Table 1 gives a value of 0.0668, or 6.68 percent.

⁶For example, Table 1 indicates a probability of 0.1587 of a value occurring that is greater than $+1\sigma$ from the mean and a probability of 0.1587 of a value occurring that is less than -1σ from the mean. Hence the probability of a value *between* $+1\sigma$ and -1σ is 68.26 percent—that is, $1.00 - (2 \times 0.1587)$.

Thus, a 6.68 percent probability exists that Investment I will have annual net cash flows less than \$205. Conversely, there is a 93.32 percent probability ($1 - 0.0668$) that the investment will have a cash flow greater than \$205.

Coefficient of Variation: A Relative Measure of Risk

The standard deviation is an appropriate measure of risk when the decision alternatives being compared are approximately equal in size (that is, have similar expected values of the outcomes) and the outcomes are estimated to have symmetrical probability distributions. Because the standard deviation is an *absolute* measure of variability,

WHAT WENT RIGHT • WHAT WENT WRONG

Long-Term Capital Management (LTCM)⁷

LTCM operated from June 1993–September 1998 as a hedge fund that invested highly leveraged private capital in arbitrage trading strategies on the financial derivative markets. LTCM's principal activity was examining interest rate derivative contracts throughout the world for evidence of very minor mispricing and then betting enormous sums on the subsequent convergence of those contracts to predictable equilibrium prices. Since the mispricing might be only several cents per thousand dollars invested, LTCM often needed to risk millions or even billions on each bet to secure a nontrivial absolute dollar return. With sometimes as many as 100 independent bets spread across dozens of different government bond markets, LTCM appeared globally diversified.

In a typical month, 60 such convergence strategies with positions in several thousand counterparty contracts would make money and another 40 strategies with a similar number of counterparties would lose money. Steadily, the profits mounted. From approximately \$1 billion net asset value (equity) in February 1994, LTCM reached \$7 billion of net asset value in January 1998. LTCM then paid out \$2.4 billion in a one-time distribution to non-partners, which equaled a 40 percent annual compound return on their investment (ROI). Shortly thereafter, in August 1998, the remaining \$4.6 billion equity shrank by 45 percent, and then one month later shrank by another 82 percent to less than \$600 million. In September 1998, the hedge fund was taken over by 14 Wall Street banks who, in exchange for inserting \$3.6 billion to cover the firm's debts, acquired 90 percent of the equity ownership. What went wrong?

One potential explanation is that such events are fully expected in an enterprise so risky that it returns a 40 percent ROI. Anticipated risk and expected return are highly positively correlated across different types of investments. However, LTCM's annual return had a standard deviation from June 1993 to June 1998 of only

11.5 percent per year as compared to 10 percent as the average for all S&P 500 stocks. In this respect, LTCM's return volatility was quite ordinary. Another potential explanation is that LTCM's \$129 billion on the June 1998 balance sheet was overwhelmed by excessive off-balance sheet assets and liabilities. Although the absolute size of the numbers is staggering (e.g., \$1.2 trillion in interest rate swaps, \$28 billion in foreign exchange derivatives, and \$36 billion in equity derivatives), LTCM's 9 percent ratio of on-balance sheet to off-balance sheet assets was similar to that of a typical securities firm (about 12 percent). Even LTCM's high financial leverage (\$129 billion assets to \$4.7 billion equity = 26 to 1) was customary practice for hedge funds.

What appears to have gone wrong for LTCM was that a default of the Russian government on debt obligations in August 1998 set in motion a truly extraordinary "flight to quality." General turmoil in the bond markets caused interest rate volatility to rise to a standard deviation of 36 percent when 3 percent would have been typical. LTCM was caught on the wrong side of many interest rate derivative positions for which no trade was available at any price. Although LTCM had "stress tested" their trading positions against so-called "3 sigma events" (a one-day loss of \$35 million), this August–September 1998 volatility proved to be a 9 sigma event (i.e., a one-day loss of \$553 million).

With massive investments highly leveraged and exposed to a 9 sigma event, LTCM hemorrhaged \$2 billion in one month. Because liquidity risk exposure of an otherwise fully diversified portfolio was to blame, many investment houses have concluded that leverage should be substantially reduced as a result of the events at LTCM.

⁷R. Lowenstein, *When Genius Failed* (New York: Random House, 2000); remarks by Dave Modest, NBER Conference, May 1999; and "Case Study: LTCM," *eRisk*, (2000).

coefficient of variation

The ratio of the standard deviation to the expected value.

A relative measure of risk.

however, it is generally not suitable for comparing alternatives of differing size. In these cases the **coefficient of variation** provides a better measure of risk.

The coefficient of variation (v) considers relative variation and thus is well suited for use when a comparison is being made between two unequally sized decision alternatives. It is defined as the ratio of the standard deviation σ to the expected value \bar{r} , or

$$v = \frac{\sigma}{\bar{r}} \quad [2.8]$$

Example**Relative Risk Measurement: Arrow Tool Company**

Arrow Tool Company is considering two investments, T and S. Investment T has expected annual net cash flows of \$100,000 and a standard deviation of \$20,000, whereas Investment S has expected annual net cash flows of \$4,000 and a \$2,000 standard deviation. Intuition tells us that Investment T is less risky because its *relative* variation is smaller. As the coefficient of variation increases, so does the relative risk of the decision alternative. The coefficients of variation for Investments T and S are computed as

Investment T:

$$\begin{aligned} v &= \frac{\sigma}{\bar{r}} \\ &= \frac{\$20,000}{\$100,000} \\ &= 0.20 \end{aligned}$$

Investment S:

$$\begin{aligned} v &= \frac{\sigma}{\bar{r}} \\ &= \frac{\$2,000}{\$4,000} \\ &= 0.5 \end{aligned}$$

Cash flows of Investment S have a larger coefficient of variation (0.50) than do cash flows of Investment T (0.20); therefore, even though the standard deviation is smaller, Investment S is the *more* risky of the two alternatives.

RISK AND REQUIRED RETURN

The relationship between risk and required return on an investment can be defined as

$$\text{Required return} = \text{Risk-free return} + \text{Risk premium} \quad [2.9]$$

The risk-free rate of return refers to the return available on an investment with no risk of default. For debt securities, no default risk means that promised interest and principal payments are guaranteed to be made. The best example of risk-free debt securities are short-term government securities, such as U.S. Treasury bills. The buyer of a U.S. government debt security always is assured of receiving the promised *principal* and *interest* payments because the U.S. government always can print more money. The risk-free return on T-bills equals the real rate of interest plus the expected rate of inflation. The second term in Equation 2.9 is a potential “reward” that an investor can expect to receive

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Example

Risk-Return Trade-Offs in Stocks, Bonds, Farmland, and Diamonds

Investors require higher rates of return on debt securities based primarily on their default risk. Bond-rating agencies, such as Moody's, Standard and Poor's, and Fitch, provide evaluations of the default risk of many corporate bonds. Moody's, for example, rates bonds on a 9-point scale from Aaa through C, where Aaa-rated bonds have the lowest expected default risk. As can be seen in Table 2.10, the yields on bonds increase as the risk of default increases, again reflecting the positive relationship between risk and required returns.

TABLE 2.10 RELATIONSHIP BETWEEN RISK AND REQUIRED RETURNS

DEBT SECURITY	YIELD
U.S. Treasury bill	3.8%
U.S. Treasury bonds (25 year +)	5.06
Aaa-rated corporate bonds	6.49
Aa-rated bonds	6.93
A-rated bonds	7.18
Baa-rated corporate bonds	7.80
Other investments	
Diamonds	3.0
Farmland	6.5
Stocks	
All U.S. stocks	10.1
Biotech stocks	12.6
Emerging market stocks	16.0

Source: Board of Governors of the Federal Reserve System, *Federal Reserve Bulletin*.

Table 2.10 also shows investment in diamonds has returned 3 percent whereas farmland has returned 6.5 percent, U.S. stocks have returned 10 percent, biotech stocks have returned 12.6 percent, and emerging market stocks have returned 16 percent compounded annually from 1970 to 2010. These compound annual returns mirror the return variance of diamonds (lowest), farmland, U.S. stocks, biotech stocks, and emerging market stocks (highest).

from providing capital for a risky investment. This *risk premium* may arise for any number of reasons. The borrower firm may default on its contractual repayment obligations (a default risk premium). The investor may have little seniority in presenting claims against a bankrupt borrower (a seniority risk premium). The investor may be unable to sell his security interest (a liquidity risk premium as we saw in the case of LTCM), or debt repayment may occur early (a maturity risk premium). Finally, the return the investor receives may simply be highly volatile, exceeding expectations during one period and plummeting below expectations during the next period. Investors generally are considered to be *risk averse*; that is, they expect, on average, to be compensated for any and all of these risks they assume when making an investment.

SUMMARY

- Demand and supply simultaneously determine equilibrium market price. The determinants of demand (supply) other than price shift the demand (supply) curve. A change in price alone leads to a change in quantity demanded (supplied) without any shift in demand (supply).
- The offer price demanders are willing to pay is determined by the marginal use value of the purchase being considered. The asking price suppliers are willing to accept is determined by the variable cost of the product or service being supplied.
- The equilibrium price of gasoline fluctuates primarily because of spikes and collapses in crude oil input prices caused at various times by supply disruptions and gluts, increasing demand in developing countries, and speculation.
- Changes in price result in *movement* along the demand curve, whereas changes in any of the other variables in the demand function result in *shifts* of the entire demand curve. Thus “changes in quantity demanded along” a particular demand curve result from price changes. In contrast, when one speaks of “changes in demand,” one is referring to shifts in the entire demand curve.
- Some of the factors that cause a shift in the entire demand curve are changes in the income level of consumers, the price of substitute and complementary goods, the level of advertising, competitors’ advertising expenditures, population, consumer preferences, time period of adjustment, taxes or subsidies, and price expectations.
- The *marginal analysis* concept requires that a decision maker determine the additional (marginal) costs and additional (marginal) benefits associated with a proposed action. If the marginal benefits exceed the marginal costs (that is, if the net marginal benefits are positive), the action should be taken.
- The *net present value* of an investment is equal to the present value of expected future returns (cash flows) minus the initial outlay.
- The net present value of an investment equals the contribution of that investment to the value of the firm and, accordingly, to the wealth of shareholders. The net present value of an investment depends on the return required by investors (the firm), which, in turn, is a function of the perceived risk of the investment.
- *Risk* refers to the potential variability of outcomes from a decision alternative. It can be measured either by the *standard deviation* (an absolute measure of risk) or *coefficient of variation* (a relative measure of risk).
- A positive relationship exists between risk and required rates of return. Investments involving greater risks must offer higher expected returns.

Exercises

Answers to the exercises in blue can be found in Appendix C at the back of the book.

1. For each of the determinants of demand in Equation 2.1, identify an example illustrating the effect on the demand for hybrid gasoline-electric vehicles such as the Toyota Prius. Then do the same for each of the determinants of supply in Equation 2.2. In each instance, would equilibrium market price increase or decrease? Consider substitutes such as plug-in hybrids, the Nissan Leaf and Chevy Volt, and complements such as gasoline and lithium ion laptop computer batteries.
2. Gasoline prices above \$3 per gallon have affected what Enterprise Rental Car Co. can charge for various models of rental cars. SUVs are \$37 with one-day return and subcompacts are \$41 with one-day return. Why would the equilibrium price of SUVs be lower than the equilibrium price of subcompacts?

Not For Sale

3. The Ajax Corporation has the following set of projects available to it:

PROJECT*	INVESTMENT REQUIRED (\$ MILLION)	EXPECTED RATE OF RETURN
A	500	23.0%
B	75	18.0
C	50	21.0
D	125	16.0
E	300	14.0
F	150	13.0
G	250	19.0

*Note: All projects have equal risk.

Ajax can raise funds with the following marginal costs:

First \$250 million	14.0%
Next 250 million	15.5
Next 100 million	16.0
Next 250 million	16.5
Next 200 million	18.0
Next 200 million	21.0

Use the marginal cost and marginal revenue concepts developed in this chapter to derive an optimal capital budget for Ajax.

4. The demand for MICHTEC's products is related to the state of the economy. If the economy is expanding next year (an above-normal growth in GNP), the company expects sales to be \$90 million. If there is a recession next year (a decline in GNP), sales are expected to be \$75 million. If next year is normal (a moderate growth in GNP), sales are expected to be \$85 million. MICHTEC's economists have estimated the chances that the economy will be either expanding, normal, or in a recession next year at 0.2, 0.5, and 0.3, respectively.
- Compute expected annual sales.
 - Compute the standard deviation of annual sales.
 - Compute the coefficient of variation of annual sales.
5. Two investments have the following expected returns (net present values) and standard deviation of returns:

PROJECT	EXPECTED RETURNS	STANDARD DEVIATION
A	\$ 50,000	\$ 40,000
B	\$250,000	\$125,000

Which one is riskier? Why?

6. The manager of the aerospace division of General Aeronautics has estimated the price it can charge for providing satellite launch services to commercial firms. Her most optimistic estimate (a price not expected to be exceeded more than 10 percent of the time) is \$2 million. Her most pessimistic estimate (a lower price than this one is not expected more than 10 percent of the time) is \$1 million. The expected value estimate is \$1.5 million. The price distribution is believed to be approximately normal.

- a. What is the expected price?
- b. What is the standard deviation of the launch price?
- c. What is the probability of receiving a price less than \$1.2 million?

Case Exercise

REVENUE MANAGEMENT AT AMERICAN AIRLINES⁸

Airlines face highly cyclical demand; American reported profitability in the strong expansion of 2006–2007 but massive losses in the severe recession of 2008–2009. Demand also fluctuates day to day. One of the ways American copes with random demand is through marginal analysis using revenue management techniques. Revenue or “yield” management (RM) is an integrated demand-management, order-booking, and capacity-planning process.

To win orders in a service industry *without slashing prices* requires that companies create perceived value for segmented classes of customers. Business travelers on airlines, for example, will pay substantial premiums for last-minute responsiveness to their flight change requests. Other business travelers demand exceptional delivery reliability and on-time performance. In contrast, most vacation excursion travelers want commodity-like service at rock-bottom prices. Although only 15–20 percent of most airlines’ seats are in the business segment, 65–75 percent of the profit contribution on a typical flight comes from this group.

The management problem is that airline capacity must be planned and allocated well in advance of customer arrivals, often before demand is fully known, yet unsold inventory perishes at the moment of departure. This same issue faces hospitals, consulting firms, TV stations, and printing businesses, all of whom must acquire and schedule capacity before the demands for elective surgeries, a crisis management team, TV ads, or the next week’s press run are fully known.

One approach to minimizing unsold inventory and yet capturing all last-minute high-profit business is to auction off capacity to the highest bidder. The auction for free-wheeling electricity works just that way: power companies bid at quarter ’til the hour for excess supplies that other utilities agree to deliver on the hour. However, in airlines, prices cannot be adjusted quickly as the moment of departure approaches. Instead, revenue managers employ large historical databases to predict segmented customer demand in light of current arrivals on the reservation system. They then analyze the expected marginal profit from holding in reserve another seat in business class in anticipation of additional “last-minute” demand and compare that seat by seat to the alternative expected marginal profit from accepting one more advance reservation request from a discount traveler.

Suppose on the 9:00 A.M. Dallas to Chicago flight next Monday, 63 of American’s 170 seats have been “protected” for first class, business class, and full coach fares but only 50 have been sold; the remaining 107 seats have been authorized for sale at a discount. Three days before departure, another advance reservation request arrives in the discount class, which is presently full. Should American reallocate capacity and

⁸Based on Robert Cross, *Revenue Management* (New York: Broadway Books, 1995); and Frederick Harris and Peter Peacock, “Hold My Place Please: Yield Management Improves Capacity Allocation Guesswork,” *Marketing Management* (Fall 1995), pp. 34–46.

Not For Sale

take on the new discount passenger? The answer depends on the marginal profit from each class and the predicted probability of excess demand (beyond 63 seats) next Monday in the business classes.

If the \$721 full coach fare has a \$500 marginal profit and the \$155 discount fare has a \$100 marginal profit, the seat in question should not be reallocated from business to discount customers unless the probability of “stocking out” in business is less than 0.20 (accounting for the likely incidence of cancellations and no-shows). Therefore, if the probability of stocking out is 0.25, the expected marginal profit from holding an empty seat for another potential business customer is \$125, whereas the marginal profit from selling that seat to the discount customer is only \$100 with certainty. Even a pay-in-advance no-refund seat request from the discount class should be refused. Every company has some viable orders that should be refused because additional capacity held in reserve for the anticipated arrival of higher profit customers is not “idle capacity” but rather a predictable revenue opportunity waiting to happen.

In this chapter, we developed the marginal analysis approach used in solving American’s seat allocation decision problem. The Appendix to Chapter 14 discusses further the application of revenue management to baseball, theatre ticketing, and hotels.

Questions

1. Make a list of some of the issues that will need to be resolved if American Airlines decides to routinely charge different prices to customers in the same class of service.
2. Would you expect these revenue management techniques of charging differential prices based on the target customers’ willingness to pay for change order responsiveness, delivery reliability, schedule frequency, and so forth to be more effective in the trucking industry, the outpatient health care industry, or the hotel industry? Why or why not?
3. Sometimes when reservation requests by deep discount travelers are refused, demanders take their business elsewhere; they “balk.” At other times, such demanders negotiate and can be “sold up” to higher fare service like United’s Economy Plus. If United experiences fewer customers balking when reservation requests for the cheapest seats are refused, should they allocate preexisting capacity to protect fewer seats (or more) for late-arriving full-fare passengers?

Not For Sale

Applications of Cost Theory

CHAPTER PREVIEW This chapter examines some of the techniques that have been developed for estimating the cost functions of production processes in actual firms. In the short run, knowledge of the firm's cost function is essential when deciding whether to accept an additional order, perhaps at less than "full cost"; whether to schedule overtime for workers; or whether to temporarily suspend operations but not close the plant. In the long run, knowledge of cost-function relationships will determine the capital investments to make, the production technology to adopt, the markets to enter, and the new products to introduce. The first part of the chapter examines various techniques for empirically estimating short-run and long-run cost functions. The second part of the chapter deals with break-even and contribution analysis—an application of cost theory that is useful in examining the profitability of a firm's operations.

MANAGERIAL CHALLENGE

How Exactly Have Computerization and Information Technology Lowered Costs at Chevron, Timken, and Merck?¹

Computerization and robotics have made output per worker higher and therefore lowered unit labor cost when it comes to processing insurance claims, redeeming coupons, or screening job resumes. Personal computers have decreased manyfold the time and talent required to perform routine work done previously with paper forms and time-consuming repetitive human tasks. However, not every business uses large numbers of PCs. How have computerization and information technology raised productivity and lowered cost so widely across other industries?

One key seems to be enhanced analytical and research and development (R&D) capability provided by computers and information technology (IT) systems. Chevron Corporation once spent anywhere from \$2 to \$4 million each to drill 10 to 12 exploratory wells before finding oil. Today, Chevron finds oil once in every five wells. The reason for the cost savings is a new technology that allows Chevron to display three-dimensional

graphs of the likely oil and gas deposits in potential oil fields. New fast parallel processors allow more calculation-intensive 3-D simulation modeling. Using only seismic data as inputs, Chevron can now model how the oil and gas deposits will shift and flow as a known field is pumped out. This allows a much more accurate location of secondary wells. As a result, overall production costs declined 16 percent industry-wide since 1991.

Timken, a \$4-billion ball-bearing manufacturer, has also used digital 3D modeling to reconfigure production processes and implement small production runs of high-profit-margin products. Timken's newest facility in North Carolina is a so-called flexible manufacturing system where order taking, limited customization of design, production scheduling, and the actual factory itself are all IT enabled and networked. Networked machine tools make it possible to build to order against precise specifications deliverable within

MANAGERIAL CHALLENGE *Continued*



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four hours rather than stockpile enormous inventories of subassemblies or insist that customers wait six to eight weeks, as was the practice before IT. Nissan recently estimated that \$3,600 in the final price of an auto is tied up in inventory expense. The build-to-order system could save the auto industry as much as \$50 billion per year out of its \$80 billion inventory cost.

Pharmaceutical R&D has experienced a similar benefit from computerization. Drug industry basic research always starts with biochemical or biogenetic modeling of the disease mechanism. In the past, once a mechanism for Hodgkin's disease or pancreatic cancer became well understood, researchers at Merck or Pfizer experimented on known active compounds one by one in time-consuming chemical trials. Successful therapies

emerged only after human trials on the promising compounds showed efficacy with few side effects. Total time to introduction of a new pharmaceutical was often longer than a decade and entailed \$1.5 billion in investments.

Today, the first stage of the basic research process remains much the same, but the second stage of dribbling chemicals into a petri dish has ended. Instead, machines controlled and automated by microchips perform thousands of reactions at once and tally the results. Human researchers then take the most likely reagents and perform much more promising experiments that culminate in human trials. The total time to discovery has been cut by more than two-thirds, and all attendant costs have declined sharply.

Discussion Questions

- Name a business that you believe has experienced declining costs attributable to computerization. Were variable costs reduced? What fixed costs increase was involved? Does it seem clear that average total cost went down? Explain.

¹Based on "The Innovators: The Rocket under the High-Tech Boom," *Wall Street Journal* (March 30, 1999); "Mass Customization," *The Economist* (July 14, 2001), pp. 64–67; and "The Flexible Factory," *BusinessWeek* (May 5, 2003), pp. 90–101.

ESTIMATING COST FUNCTIONS

To make optimal pricing and production decisions, the firm must have knowledge of the shape and characteristics of its short-run cost function. A *cost function* is a schedule, graph, or mathematical relationship showing the total, average, or marginal cost of producing various quantities of output. To decide whether to accept or refuse an order offered at some particular price, the firm must identify exactly what variable cost and direct fixed costs the order entails. A capability to estimate the short-run cost function is therefore crucial. In contrast, the long-run cost function is associated with the longer-term planning period in which all the inputs to the production process are variable and no restrictions are placed on the amount of an input that can be employed in the production process. Consequently, all costs, including indirect fixed costs such as headquarters facility costs, are avoidable and therefore relevant to cost estimates.

Issues in Cost Definition and Measurement

Recall that economic cost is represented by the value of opportunities forgone, whereas accounting cost is measured by the outlays that are incurred. Some companies, such as Deep Creek Mining, record the cost of their own output (the crude oil, coal, or gas) shipped downstream to their refining-and-processing operations as expenses at the world market price on the day of shipment (i.e., at their opportunity cost). Other companies account for these same resources as their out-of-pocket expenses. If extraction costs of the company being studied are low (e.g., with Kentucky coal or West Texas intermediate crude or Persian Gulf oil), these two cost methods will diverge because the equilibrium market price is always determined by the considerably higher cost of the marginal producer (e.g., an oil platform in the North Sea).

Similar problems arise in measuring variable costs (i.e., costs that vary with output). Some companies employ only direct accounting costs, including materials, supplies, direct labor costs, and any direct fixed costs avoidable by refusing the batch order in question. Direct costs exclude all overhead and any other fixed cost that must be allocated (so-called indirect fixed costs). For batch decisions about whether to accept or refuse an order for a proposed charter air flight, a special production run, or a customer's proposed change order, these estimates of variable plus direct fixed costs are needed. For other questions, such as offering a customized design, however, some indirect accounting cost for the IT system that allows customized design would be an appropriate inclusion in the cost data.

Several other cost measurement issues arise with depreciation. Conceptually, depreciation can be divided into two components: *time depreciation* represents the decline in value of an asset associated with the passage of *time*, and *use depreciation* represents the decline in value associated with *use*. For example, annual body style changes in the automobile industry or technical progress in speed and memory of personal computers renders products and production processes obsolete. Note that such time depreciation is completely independent of the rate of output at which the asset is actually operated. Because only use depreciation varies with the rate of output, only use depreciation is relevant in determining the shape of the cost-output relationship. However, accounting data on depreciation seldom break out use depreciation costs separately. Instead, the depreciation of the value of an asset over its life cycle is usually determined by arbitrary tax regulations. Finally, capital asset values (and their associated depreciation costs) are often stated in terms of historical costs rather than in terms of replacement costs. In periods of rapidly increasing price levels, this approach will tend to understate true economic depreciation costs. These limitations need to be kept in mind when interpreting the cost-output relationship for a firm with numerous capital assets, such as an airline.

Controlling for Other Variables

In addition to being a function of the output level of the firm, cost is a function of other factors, such as output mix, the length of production runs, employee absenteeism and turnover, production methods, input costs, and managerial efficiency.

To isolate the cost-output relationship itself, one must control for these other influences by:

- *Deflating or detrending the cost data.* Whenever wage rates or raw material prices change significantly over the period of analysis, one can deflate the cost data to reflect these changes in factor prices. Provided suitable price indices are available or

can be constructed, costs incurred at different points in time can be restated as inflation-adjusted real costs.²

- *Using multiple regression analysis.* Suppose a firm believes that costs should decline gradually over time as a result of innovative worker suggestions. One way to incorporate this effect into the cost equation would be to include a time trend t as an additional explanatory variable:

$$C = f(Q, t) \quad [9.1]$$

Other possible control variables include the number of product lines, the number of customer segments, and the number of distribution channels.

The Form of the Empirical Cost-Output Relationship

The total cost function in the short run (*SRTC*), as hypothesized in economic theory, is an S-shaped curve that can be represented by a cubic relationship:

$$SRTC = a + bQ + cQ^2 + dQ^3 \quad [9.2]$$

The familiar U-shaped marginal and average cost functions then can be derived from this relationship. The associated marginal cost function is

$$MC = \frac{d(SRTC)}{dQ} = b + 2cQ + 3dQ^2 \quad [9.3]$$

The average total cost function is

$$ATC = \frac{SRTC}{Q} = \frac{a}{Q} + b + cQ + dQ^2 \quad [9.4]$$

The cubic total cost function and its associated marginal and average total cost functions are shown in Figure 9.1(a). If the results of a regression analysis indicate that the cubic term (Q^3) is not statistically significant, then short-run total cost can be represented by a quadratic relationship:

$$SRTC = a + bQ + cQ^2 \quad [9.5]$$

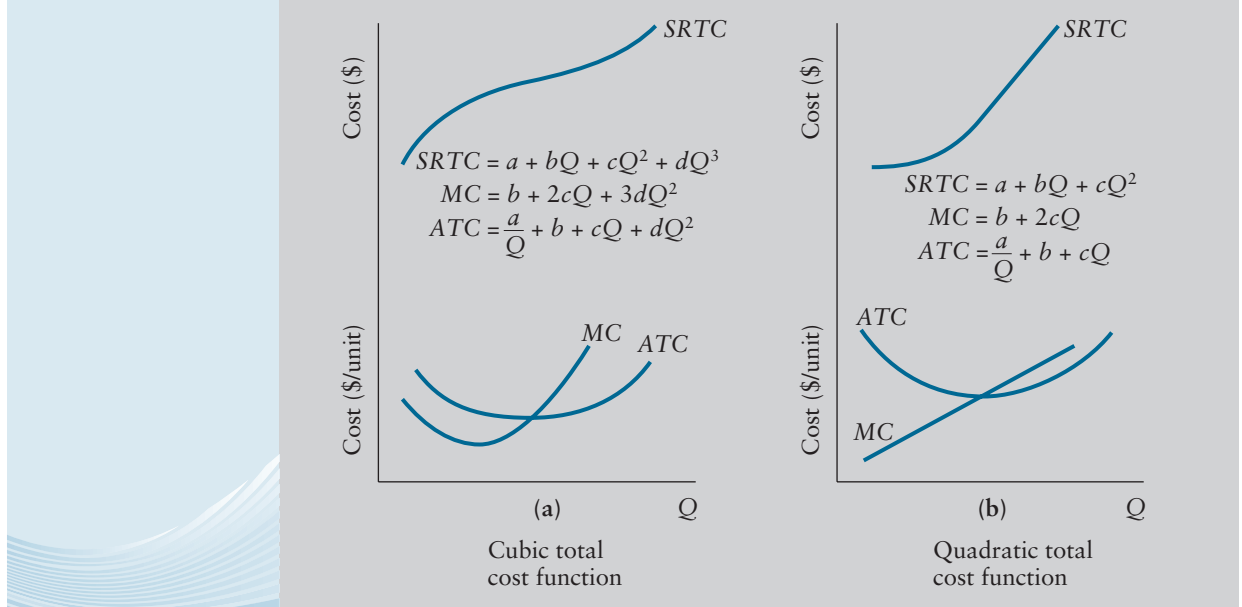
as illustrated in Figure 9.1(b). In this quadratic case, total costs increase at an increasing rate throughout the typical operating range of output levels. The associated marginal and average cost functions are

$$MC = \frac{d(SRTC)}{dQ} = b + 2cQ \quad [9.6]$$

$$ATC = \frac{SRTC}{Q} = \frac{a}{Q} + b + cQ \quad [9.7]$$

As can be seen from Equation 9.6, this quadratic total cost relationship implies that marginal costs increase linearly as the output level is increased.

²Two assumptions are implicit in this approach: No substitution takes place between the inputs as prices change, and changes in the output level have no influence on the prices of the inputs. For more automated plants that incorporate only maintenance personnel, plant engineers, and material supplies, these assumptions fit the reality of the production process quite well.

FIGURE 9.1 Polynomial Cost-Output Relationships

WHAT WENT RIGHT • WHAT WENT WRONG

Boeing: The Rising Marginal Cost of Wide-Bodies³

Boeing and Airbus provide all the wide-bodied jets the world needs. Boeing 747s, 767s, and 777s typically have a 70 percent share of the worldwide market, but Airbus accepted a majority of the new orders in 1994–1995 and doubled its output rate, especially on smaller planes, from 126 to 232 planes per year. Some analysts think Boeing should have given up even more of the order flow. Why?

One reason is that until recently, incremental orders at Boeing necessitated redrawing and duplicating the thousands of engineering diagrams that determine how 200,000 employees assemble any particular customer's plane. Rather than doing mass customization from common platforms, Boeing assembles one plane at a time with new drawings for each \$150 million wide-body ordered. Eventually, incremental variable costs must rise as designers and shop floors get congested with new instructions and diagrams.

With backorders running to almost 1,000 planes companywide in the mid-1990s, Boeing boosted production from 180 to 560 commercial jets per year. At the final assembly plant for Boeing wide-bodies in Everett, Washington, just north of Seattle, throughput was increased from 15 planes

per month to 21 planes per month (i.e., by 40 percent). To increase production rates, Boeing needed to split bottlenecked assembly stations into parallel processes, which entailed the hiring of additional assembly workers and massive overtime. Boeing also increased the production rate of final assembly by contracting out more subassemblies. Splitting bottlenecked assembly stations or contracting out subassemblies substantially increases Boeing's variable costs.

In the late 1990s, wide-body prices did not rise because of intense competitive pressure from Airbus, but Boeing's marginal costs certainly did. As a result, for a while in the late 1990s, every wide-body plane delivered had a price less than its marginal cost (i.e., a negative gross profit margin). Of course, eventually such orders must be refused. In 2000, Boeing did slow the production throughput rate at Everett back to 15 wide-bodies per month in order to return to profitability. Today, the well-equipped 747-400 aircraft earns as much as \$45 million in operating profits above its variable cost.

³Based on "Boeing's Trouble," *Wall Street Journal* (December 16, 1998), p. A23; and Everett, Washington, site visit.

But rising, not constant, marginal cost is characteristic of many manufacturing environments. On the other hand, some information services companies, such as IBM Global Services or network-based software companies such as Microsoft, may at times experience declining marginal costs.

Statistical Estimation of Short-Run Cost Functions

Short-run cost functions have been estimated for firms in a large number of different industries—for example, food processing, furniture, railways, gas, coal, electricity, hospitality, steel, and cement.

Statistical Estimation of Long-Run Cost Functions

Long-run costs can be estimated over a substantial period of time in a single plant (time-series data) or with multiple plants operating at different rates of output (cross-sectional data). The use of cross-sectional data assumes that each firm is using its fixed plant and equipment and variable inputs to accomplish min *LRAC* production for that plant size along the envelop of *SRAC* curves we studied in Chapter 8.

The use of time-series data assumes that input prices, the production technology, and the products offered for sale remain unchanged. Both methods, therefore, require heroic assumptions, but cross-sectional data are more prevalent in estimating long-run cost functions.

Example

Short-Run Cost Function for Multi-Product Food Processing

In a study of a British food processing firm, Johnston constructed individual cost functions for 14 different products and an overall cost function for the firm.⁴ Weekly data for nine months were obtained on the physical production of each type of product and total direct costs of each product (subdivided into the four categories of materials, labor, packing, and freight). Indirect costs (such as salaries, indirect labor, factory charges, and laboratory expenses) remained fairly constant over the time period studied and were excluded from the analysis. A price index for each category of direct costs for each product was obtained from government sources and used to deflate all four sets of input costs, yielding a weekly deflated direct cost for each product. For the individual products, output was measured by physical production (quantity). For the firm as a whole, an index of aggregate output was constructed by weighting the quantities of each product by its selling price and summing over all products produced each period.

For the 14 different products and for the overall firm, the linear cost function gave an excellent fit between direct cost and output. Therefore, Johnston concluded that total direct costs were a linear function of output, and marginal costs were constant over the observed ranges of output.

⁴See Jack Johnston, *Statistical Cost Analysis* (New York: McGraw-Hill, 1960).

Example**Short-Run Cost Functions: Electricity Generation⁵**

Another study by Johnston of the costs of electric power generation in Great Britain developed short-run cost functions for a sample of 17 different firms from annual cost-output data on each firm. To satisfy the basic conditions underlying the short-run cost function, only those firms whose capital equipment remained constant in size over the period were included in the sample. The output variable was measured in kilowatt-hours (kWh). The cost variable was defined as the “working costs of generation” and included: (1) fuel; (2) salaries and wages; and (3) repairs and maintenance, oil, water, and stores. This definition of cost does not correspond exactly with variable costs as long as maintenance is scheduled so as to just offset wear and tear from use. Each of the three cost categories was deflated using an appropriate price index. A cubic polynomial function with an additional linear time trend variable was fitted to each of 17 sets of cost-output observations.

The results of this study did *not* support the existence of a nonlinear cubic or quadratic cost function. The cubic term, Q^3 , was not statistically significant in any of the regressions, and the quadratic term, Q^2 , was statistically significant in only 5 of the 17 cost equations. A typical linear total cost function is given by

$$C = 18.3 + 0.889Q - 0.639T$$

where C = variable costs of generation, Q = annual output (millions of kilowatt-hours), and T = time (years). The equation “explained” 97.4 percent of the variation in the cost variable.

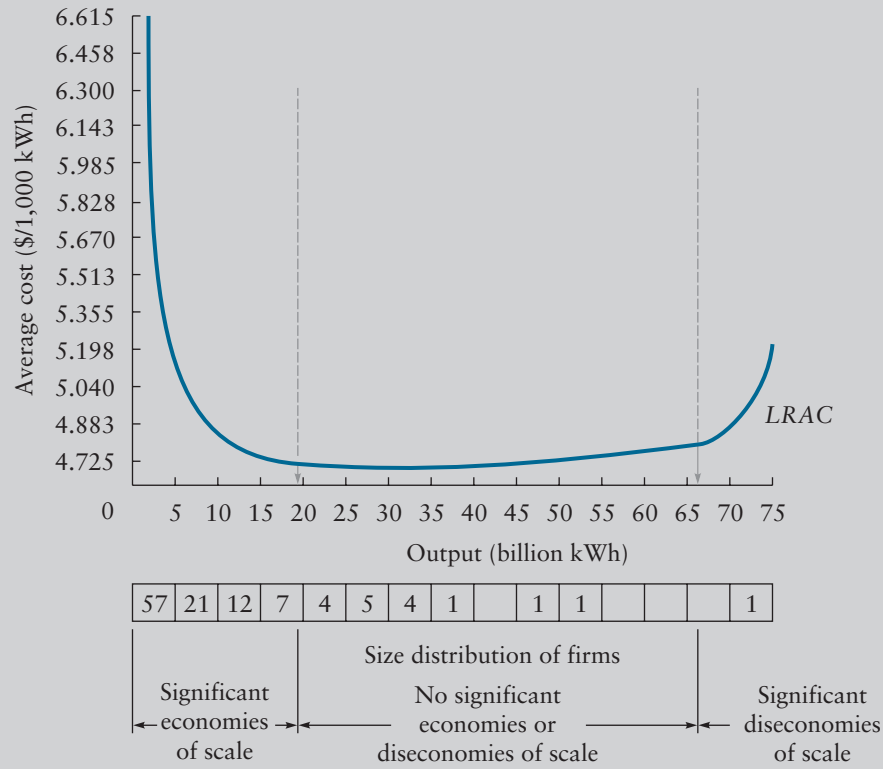
The results of the two Johnston studies are similar to those found in many other cost studies—namely, that short-run total costs tend to increase *linearly* over the ranges of output for which cost-output data are available. In other words, short-run average costs tend to decline and marginal costs tend to be constant over the “typical” or “normal” operating range of the firm. At higher rates of output, we would expect to see rising marginal cost, but, of course, this circumstance is exactly what firms try to avoid. Recall Boeing’s experience in producing too many 747s per month.

⁵Ibid., pp. 44–63.

Determining the Optimal Scale of an Operation

The size at which a company should attempt to establish its operations depends on the extent of the scale economies and the extent of the market. Some firms can operate at minimum unit cost using a small scale. Consider a licensed street vendor of leather coats. Each additional sale entails variable costs for the coat, a few minutes of direct labor effort to answer potential customers’ questions, and some small allocated cost associated with the step-van or other vehicle where the inventory is stored and hauled from one street sale location to another. Ninety-nine percent of the operating cost is the variable cost of an additional leather coat per additional sale. Long-run average cost will be essentially flat, constant at approximately the wholesale cost of a leather coat. As a result, in street vending, a small-scale operation will be just as efficient as a large-scale operation.

FIGURE 9.2 Average Cost Function for U.S. Electric Utility Firms



Example

Long-Run Cost Functions: Electricity Generation⁶

In a cross-sectional study of U.S. electric utility companies, Christensen and Greene used a logarithmic model to test for the presence of economies and diseconomies of scale. The long-run average cost curve (*LRAC*) using data on 114 firms is shown in Figure 9.2. The bar below the graph indicates the number of firms in each interval. Below 19.8 billion kWh (left arrow in graph), significant economies of scale were found to exist. The 97 firms in this range accounted for 48.7 percent of the total output. Between 19.8 and 67.1 billion kWh (right arrow in the graph), no significant economies of scale were present. The 16 firms in this range accounted for 44.6 percent of the total output. Above 67.1 billion kWh, diseconomies of scale (one firm and 6.7 percent of total output) were found.

⁶L. R. Christensen and W. H. Greene, "Economies of Scale in U.S. Electric Power Generation," *Journal of Political Economy* 84:4 (August 1976).

Example**Scale Economies in the Traditional Cable Industry: Time-Warner⁷**

Telephone landlines and traditional cable TV businesses have cost characteristics similar to electric utilities. Once the wires have been put in place, the incremental cost of extending TV or telephone service to another household is small. The extent of the scale economies in such industries may warrant licensing only one cable company or one local telephone service provider. In fact, municipalities have historically issued an exclusive service contract to such public utilities. The rationale was that one firm could service the whole market at much lower cost than several firms dividing the market and failing therefore to realize all of the available scale economies.

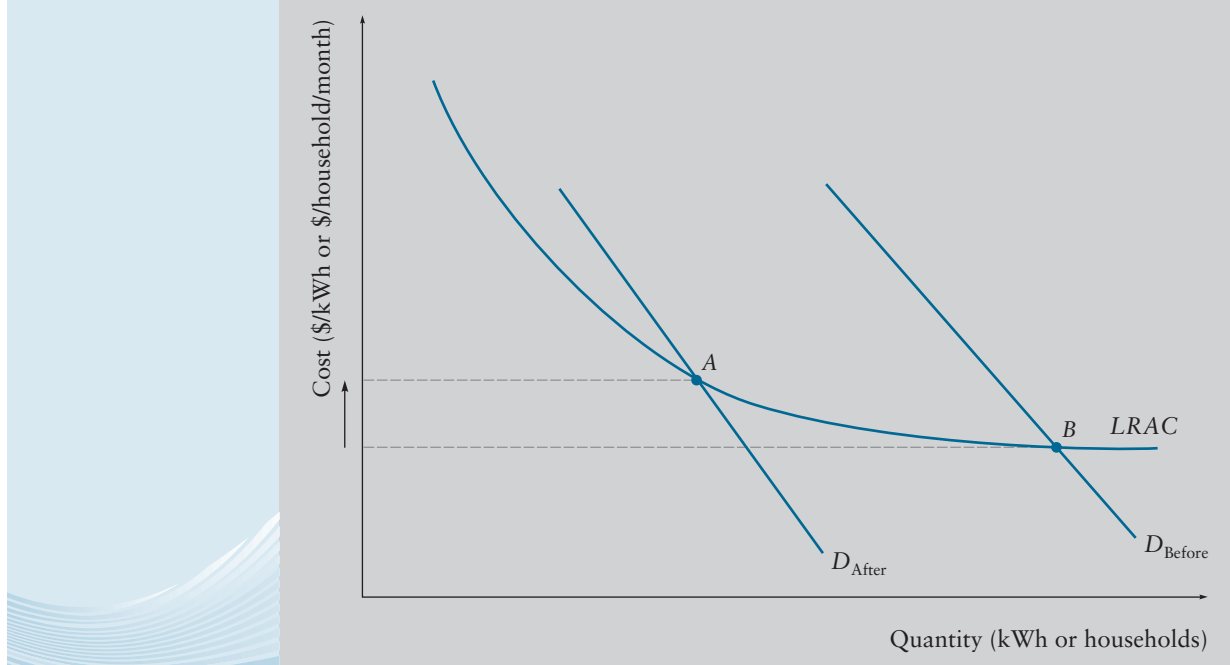
However, remember that the optimal scale of operation of any facility, even a declining cost facility, is limited by the extent of the market. The expansion of the cable TV market has always been limited by the availability of videocassette recorders, DVD players, and services such as NetFlix because they are inexpensive, convenient entertainment substitutes. As a result, the potential scale economies suggested by industrial engineering studies of cable TV operations have never been fully realized.

In addition, both telephone and cable TV companies are now facing new wireless alternative technologies. Satellite-based digital television and cell phones have cut deeply into the market once reserved exclusively for monopoly licensed communications companies. As a result, the average unit cost in these cable-based businesses increased from B to A as volume declined (see Figure 9.3). Consequently, the price required to break even has necessarily risen. Of course, that sets in motion a vicious circle; the higher the cost-covering price, the more customers the cable TV and telephone companies lose to wireless alternatives.

⁷See W. Emmons and R. Prager, "The Effects of Market Structure in the U.S. Cable Television Industry," *Rand Journal of Economics* 28:4 (Winter 1997), pp. 732–750.

In contrast, hydroelectric power plants, have few variable costs of any kind. Instead, essentially all the costs are fixed costs associated with buying the land that will be flooded, constructing the dam, and purchasing the huge electrical generator equipment. Thereafter, the only variable inputs required are a few lubricants and maintenance workers. Consequently, a hydroelectric power plant has long-run average total costs that decline continuously as the company spreads its enormous fixed cost over additional sales by supplying power to more and more households. Similarly, electric distribution lines (the high-tension power grids and neighborhood electrical conduits) are a high-fixed-cost and low-variable-cost operation. In the electrical utility industry, large-scale operations therefore incur lower unit cost than small-scale operations, as demonstrated in Figure 9.2.

"Freewheeling" in the electrical utility industry has similar effects. When industrial and commercial electricity buyers (e.g., a large assembly plant or hospital) were allowed in January 2003 to contract freely with low-cost power suppliers elsewhere in the state or even several states away, the local public utility experienced "stranded costs." That is, the high initial fixed costs of constructing dams, power plants, and distribution lines were left behind as sales volume declined and local customers opted out. If the costs

FIGURE 9.3 Fixed Costs Stranded by Freewheeling Electricity and Satellite-Based TV Signals**economies of scope**

Economies that exist whenever the cost of producing two (or more) products jointly by one plant or firm is less than the cost of producing these products separately by different plants or firms.

engineering cost techniques

A method of estimating cost functions by deriving the least-cost combination of labor, capital equipment, and raw materials required to produce various levels of output, using only industrial engineering information.

involved had been mostly variable, the local power utilities could have simply cut costs and operated profitably at smaller scale. Unfortunately, however, the costs are mostly fixed and unavoidable, so unit costs will unavoidably rise as the number of customers served declines. Consequently, the advantages of additional competition for lowering prices to consumers are projected to be almost completely offset by the rise in unit costs caused by reduced scale.⁸

Economies of Scale versus Economies of Scope

Economies of scope occur whenever inputs can be shared in the production of different products. For example, in the airline industry, the cost of transporting both passengers and freight on a single airplane is less than the cost of using two airplanes to transport passengers and freight separately. Similarly, commercial banks that manage both credit card-based unsecured consumer loans and deeded property-secured mortgage loans can provide each activity at lower cost than they could be offered separately. These cost savings occur independent of the scale of operations; hence they are distinguished from economies of scale.

Engineering Cost Techniques

Engineering cost techniques provide an alternative way to estimate long-run cost functions without using accounting cost data. Using production data, the engineering

⁸M. Maloney and R. McCormick, *Customer Choice, Consumer Value* (Washington, DC: Citizens for a Sound Economy Foundation, 1996).


Example

Economies of Scope in the Banking Industry

A number of empirical studies have attempted to estimate economies of scale and scope in the banking industry, which includes commercial banks, savings and loan associations, and credit unions. A survey article by Jeffrey Clark compiled the results of 13 of these studies.⁹ Possible sources of production economies in financial institutions include the following:

- *Specialized labor.* A larger depository institution may be able to employ more specialized labor (e.g., computer programmers, cash managers, investment specialists, and loan officers) in producing its services. If the expertise of these workers results in the processing of a higher volume of deposit and loan accounts per unit of labor, then larger institutions will experience lower per-unit labor costs compared with smaller institutions.
- *Computer and telecommunications technology.* Once the large setup, or fixed, costs are incurred, computer and electronic funds transfer systems can be used to process additional transactions at small additional costs per transaction. Spreading the fixed costs over a higher volume of transactions may permit the larger firm to achieve lower average total costs.
- *Information.* Credit information about loan applicants must be gathered and analyzed before lending decisions are made. However, once gathered, this credit information can be reused, usually at little additional cost, in making decisions about lending to the institution's customers. For example, credit information gathered in making mortgage loans can also be used in making automobile and other personal loans. Thus, larger financial institutions, which offer a wide array of different types of credit, may realize economies of scope in information gathering. That is, the cost of mortgage and auto installment lending done jointly is lower than the total cost of both when each is done separately.

All the studies reviewed by Clark employed a logarithmic cost function. The following conclusions were derived:

- Some evidence indicates economies of scope between consumer and mortgage lending.
- Significant overall (i.e., firm-specific) economies of scale occur only at relatively low levels of output (less than \$100 million in deposits). Beyond that point, most studies found an L-shaped long-run average cost curve where average total cost falls steeply at low levels of output and then flattens out and becomes horizontal. In this respect, banking *LRAC* closely mirrors the shape of the *LRAC* in representative manufacturing.

⁹Jeffrey A. Clark, "Economies of Scale and Scope at Depository Financial Institutions: A Review of the Literature," Federal Reserve Bank of Kansas City, *Economic Review* (September/October 1988), pp. 16–33.

approach attempts to determine the least-cost combination of labor, capital equipment, and raw materials required to produce various levels of output. Engineering methods offer a number of advantages over statistical methods in examining economies of scale. First, it is generally much easier with the engineering approach to hold constant such factors as input prices, product mix, and product efficiency, allowing one to isolate the effects on costs of changes in output. Second, use of the engineering method avoids some of the cost-allocation and depreciation problems encountered when using accounting data.

Example

The Survivor Technique: Steel Production

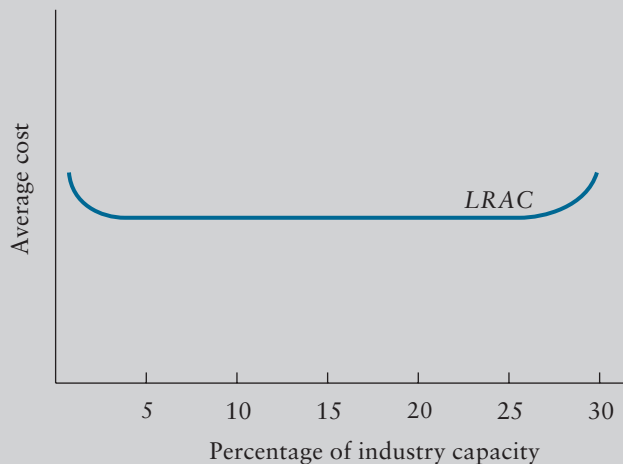
The survivor technique has been used to examine the long-run cost functions in steel ingot production by open-hearth or Bessemer processes. Based on the data in Table 9.1, Stigler developed the sleigh-shaped long-run average cost function for steel ingot production shown in Figure 9.4. Because of the declining percentages at the lowest levels of output and at extremely high levels of output, Stigler concluded that both were relatively inefficient size classes. The intermediate size classes (from 2.5 to 27.5 percent of industry capacity) represented the range of optimum size because these size classes grew or held their shares of capacity. Stigler also applied the survivor technique to the automobile industry and found an L-shaped average cost curve, indicating no evidence of diseconomies of scale at large levels of output.

TABLE 9.1 DISTRIBUTION OF STEEL INGOT CAPACITY BY RELATIVE SIZE OF COMPANY

COMPANY SIZE (PERCENTAGE OF TOTAL INDUSTRY CAPACITY)	PERCENTAGE OF INDUSTRY CAPACITY			NUMBER OF COMPANIES		
	1930	1938	1951	1930	1938	1951
Under ½	7.16	6.11	4.65	39	29	22
½ to 1	5.94	5.08	5.37	9	7	7
1 to 2½	13.17	8.30	9.07	9	6	6
2½ to 5	10.64	16.59	22.21	3	4	5
5 to 10	11.18	14.03	8.12	2	2	1
10 to 25	13.24	13.99	16.10	1	1	1
25 and over	38.67	35.91	34.50	1	1	1

Source: George J. Stigler, “The Economies of Scale,” *Journal of Law and Economics* (October 1958). Reprinted by permission.

FIGURE 9.4 Long-Run Average Costs of Steel Ingot Production



In a study designed to isolate the various sources of scale economies within a plant, Haldi and Whitcomb collected data on the cost of individual units of equipment, the initial investment in plant and equipment, and on operating costs. They noted that “in many basic industries such as petroleum refining, primary metals, and electric power, economies of scale are found in very large plant sizes (often the largest built or contemplated).”¹⁰ Few (if any) firms were observed operating beyond these minimum efficient scale plant sizes.

The Survivor Technique

It is also possible to detect the presence of scale economies or diseconomies without having access to any cost data. The **survivor technique** involves classifying the firms in an industry by size and calculating the share of industry output coming from each size class over time.¹¹ If the share decreases over time, then this size class is presumed to be relatively inefficient and to have higher average costs. Conversely, an increasing share indicates that the size class is relatively efficient and has lower average costs. The rationale for this approach is that competition will tend to eliminate those firms whose size is relatively inefficient, allowing only those size firms with lower average costs to survive.

Despite its appeal, the survivor technique does have one serious limitation. Because the technique does not use actual cost data in the analysis, it cannot assess the *magnitude* of the cost differentials between firms of varying size and efficiency.

A Cautionary Tale

One final note of caution: The concept of average total costs (ATC) per unit of output (i.e., so-called unit costs), so prominent in our recent discussion of scale economies, is seldom useful for managerial decision making. Indeed, making output or pricing decisions based on ATC is dead wrong. AVC and marginal cost determine optimal shutdown, optimal output, and optimal price decisions. Managers in prominent companies like British Telephone have been fired over this mistake when they included headquarters expense and other corporate overhead in a pricing decision for an incremental new account. So, get in the habit of avoiding the use of unit costs in your decision problem reasoning. Reserve unit costs for describing, debating, and planning issues related to scale economies and diseconomies alone.

BREAK-EVEN ANALYSIS

Many of the planning activities that take place within a firm are based on anticipated levels of output. The study of the interrelationships among a firm’s sales, costs, and operating profit at various anticipated output levels is known as **break-even analysis**.

Break-even analysis is based on the revenue-output and cost-output functions of microeconomic theory. These functions are shown together in Figure 9.5. Total revenue is equal to the number of units of output sold multiplied by the price per unit. Assuming that the firm can sell additional units of output only by lowering the price, the total revenue curve TR will be concave (inverted U shaped), as indicated in Figure 9.5.

The difference between total revenue and total cost at any level of output represents the total profit that will be obtained. In Figure 9.5, total profit TP at any output level is given by the vertical distance between the total revenue TR and total cost TC curves. A break-even situation (zero profit) occurs whenever total revenue equals total cost. Below an output level of Q_1 , losses will be incurred because $TR < TC$. Between Q_1 and Q_3 ,

survivor technique

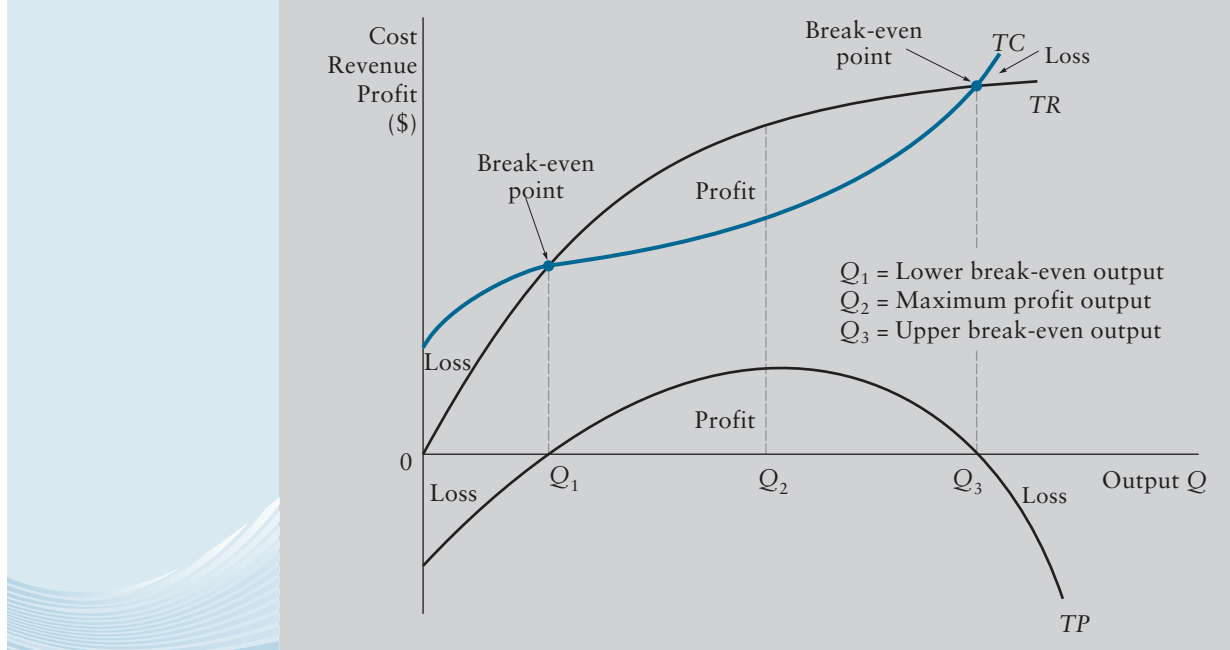
A method of estimating cost functions from the shares of industry output coming from each size class over time. Size classes whose shares of industry output are increasing (decreasing) over time are presumed to be relatively efficient (inefficient) and have lower (higher) average costs.

break-even analysis

A technique used to examine the relationship among a firm’s sales, costs, and operating profits at various levels of output.

¹⁰J. Haldi and D. Whitcomb, “Economies of Scale in Industrial Plants,” *Journal of Political Economy* 75, no. 1 (August 1967), pp. 373–385.

¹¹G. J. Stigler, *The Organization of Industry* (Homewood, IL: Richard D. Irwin 1968), Chapter 7. For other examples of the use of the survivor technique, see H. E. Ted Frech and Paul B. Ginsburg, “Optimal Scale in Medical Practice: A Survivor Analysis,” *Journal of Business* (January 1974), pp. 23–26.

FIGURE 9.5 Generalized Break-Even Analysis**Example****Boeing 777 Exceeds Break-Even Sales Volume¹²**

Boeing and Airbus, for example, are constantly calculating and recalculating their break-even sales volumes as unanticipated development costs arise on their new planes. The new double-decked jumbo jet, the Airbus 380, has \$11.7 billion in development cost requiring 259 planes at undiscounted prices to break even. Advance orders have only secured 160, much less than the break-even amount. Although Airbus has sold more total planes than Boeing in recent years, Boeing has dominated the wide-bodied submarket for larger jets with a 70 percent market share. For example, by 2006 Boeing had secured 155 orders for its 777 long-haul jet whereas Airbus had orders for only 15 of its competing Airbus 340s. Break-even appears far off on the 340s as well.

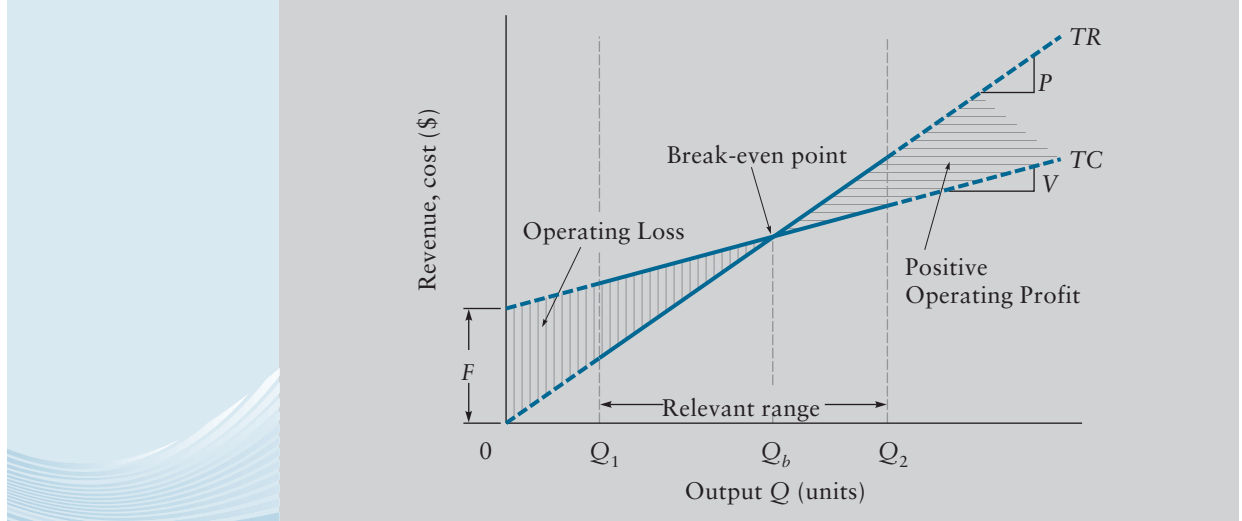
¹²“Testing Times,” *The Economist* (April 1, 2006), p. 56.

profits will be obtained because $TR > TC$. At output levels above Q_3 , losses will occur again because $TR < TC$. Total profits are maximized within the range of Q_1 to Q_3 ; the vertical distance between the TR and TC curves is greatest at an output level of Q_2 .

We now discuss both a graphical and an algebraic method of solving break-even problems.

Graphical Method

Constant selling price per unit and a constant variable cost per unit yield the linear TR and TC functions illustrated in Figure 9.6, which shows a basic linear break-even chart. Total cost is computed as the sum of the firm’s fixed costs F , which are independent of

FIGURE 9.6 Linear Break-Even Analysis Chart

the output level, and the variable costs, which increase at a constant rate of VC per unit of output. Operating profit is equal to the difference between total revenues (TR) and total (*operating*) costs (TC).

The break-even point occurs at point Q_b in Figure 9.5, where the total revenue and the total cost functions intersect. If a firm's output level is below this break-even point (i.e., if $TR < TC$), it incurs *operating losses*. If the firm's output level is above this break-even point (if $TR > TC$), it realizes *operating profits*.

Algebraic Method

To determine a firm's break-even point algebraically, one must set the total revenue and total (operating) cost functions equal to each other and solve the resulting equation for the break-even volume. Total revenue is equal to the selling price per unit times the output quantity:

$$TR = P \times Q \quad [9.8]$$

Total (operating) cost is equal to fixed plus variable costs, where the variable cost is the product of the variable cost per unit times the output quantity:

$$TC = F + (V \times Q) \quad [9.9]$$

Setting the total revenue and total cost expressions equal to each other and substituting the break-even output Q_b for Q results in

$$TR = TC$$

or

$$PQ_b = F + VQ_b \quad [9.10]$$

Finally, solving Equation 9.10 for the break-even output Q_b yields¹³

¹³Break-even analysis also can be performed in terms of dollar *sales* rather than *units* of output. The break-even dollar sales volume S_b can be determined by the following expression:

$$S_b = \frac{F}{1 - V/P}$$

where V/P is the variable cost ratio (calculated as variable cost per dollar of sales).

$$\begin{aligned}
 PQ_b - VQ_b &= F \\
 (P - V)Q_b &= F \\
 Q_b &= \frac{F}{P - V}
 \end{aligned}
 \tag{9.11}$$

contribution margin

The difference between price and variable cost per unit.

The *difference* between the selling price per unit and the variable cost per unit, $P - V$, is referred to as the **contribution margin**. It measures how much each unit of output contributes to meeting fixed costs and operating profits. Thus, the break-even output is equal to the fixed cost divided by the contribution margin.

Example**Break-Even Analysis: Allegan Manufacturing Company**

Assume that Allegan manufactures one product, which it sells for \$250 per unit (P). Variable costs (V) are \$150 per unit. The firm's fixed costs (F) are \$1 million. Substituting these figures into Equation 9.11 yields the following break-even output:

$$\begin{aligned}
 Q_b &= \frac{\$1,000,000}{\$250 - \$150} \\
 &= 10,000 \text{ units}
 \end{aligned}$$

Allegan's break-even output can also be determined graphically, as shown in Figure 9.7.

Another illustration would be to use break-even analysis to approve or reject a batch sale promotion. Suppose that in the previous example, the \$1 million is a trade rebate to elicit better shelf location for Allegan's product. If the estimated effect of this promotion is additional sales of 9,000 units, which is less than the break-even output, the change in total contributions will fall below the \$1 million promotion cost (i.e., $[\$250 - \$150] \times 9,000 < \$1,000,000$). Therefore, the promotion plan should be rejected.

Because a firm's break-even output is dependent on a number of variables—in particular, the price per unit, variable (operating) costs per unit, and fixed costs—the firm may wish to analyze the effects of changes in any of the variables on the break-even output. For example, it may wish to consider either of the following:

1. Change the selling price.
2. Substitute fixed costs for variable costs.

Example**Break-Even Analysis: Allegan Manufacturing Company (continued)**

Assume that Allegan increased the selling price per unit P' by \$25 to \$275. Substituting this figure into Equation 9.11 gives a new break-even output:

$$\begin{aligned}
 Q'_b &= \frac{\$1,000,000}{\$275 - \$150} \\
 &= 8,000 \text{ units}
 \end{aligned}$$

(Continued)

This outcome can also be seen in Figure 9.8, in which an increase in the price per unit increases the slope of the total revenue function TR/Q and reduces the break-even output.

Rather than increasing the selling price per unit, Allegan's management may decide to substitute fixed costs for variable costs in some aspect of the company's operations. For example, as labor wage rates increase over time, many firms seek to reduce operating costs through automation, which in effect represents the substitution of fixed-cost capital equipment for variable-cost labor. Suppose Allegan determines that it can reduce labor costs by \$25 per unit by leasing \$100,000 of additional equipment. Under these conditions, the firm's new level of fixed costs F' would be $\$1,000,000 + \$100,000 = \$1,100,000$. Variable costs per unit V' would be $\$150 - \$25 = \$125$. Substituting $P = \$250$ per unit, $V' = \$125$ per unit, and $F' = \$1,100,000$ into Equation 9.11 yields a new break-even output:

$$\begin{aligned} Q'_b &= \frac{\$1,000,000}{\$250 - \$125} \\ &= 8,800 \text{ units} \end{aligned}$$

Graphically, the effect of this change in cost fixity of the operations is to raise the intercept on the vertical axis, decrease the slope of the total (operating) cost function TC' , and reduce the break-even output.

FIGURE 9.7 Linear Break-Even Analysis Chart for the Allegan Manufacturing Company

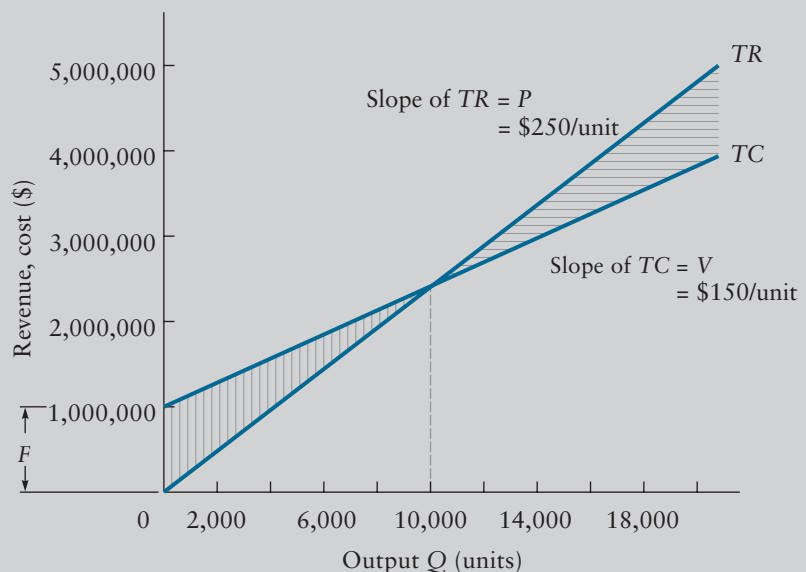
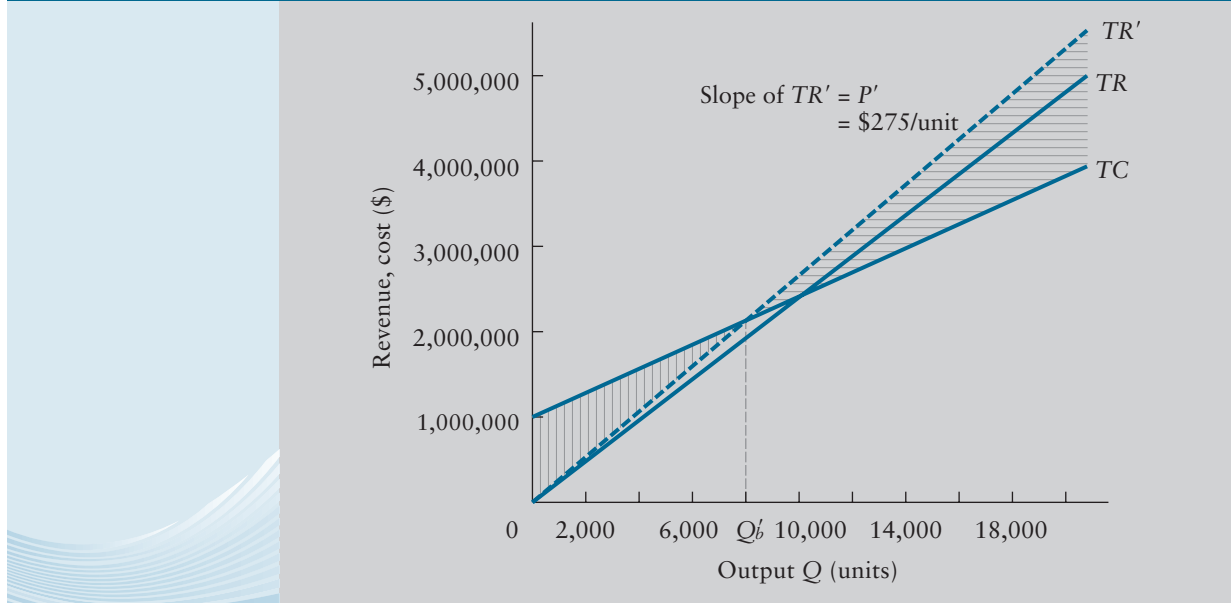


FIGURE 9.8 Linear Break-Even Analysis Chart for the Allegan Manufacturing Company Showing the Effects of a Price Increase**Example****Fixed Costs and Production Capacity at General Motors¹⁴**

In an industry with 17 million unit sales annually, GM admitted in March 2002 that it needed to reduce automobile production capacity by 1 million cars per year to match its current sales of 5 million cars. It represented the second time in its 100-year history (1988 being the earlier event) that the company had significantly shrunk its capacity. As part of its decision to reduce its size, GM planned to close 10 of its U.S. automobile assembly lines.

In the past, GM alternated between (1) building all the cars it could produce and then using costly clearance sales to attract buyers, and (2) reducing output by running plants below capacity through a slowdown in the pace of the assembly line or elimination of an entire shift. The new strategy called for the company to use 100 percent of its American automobile production capacity five days a week with two shifts per day. If automobile demand increased above this capacity level, third-shift operations would be used to boost production. Ford had been following this strategy for some time.

In effect, GM and Ford were trading off lower fixed costs over the entire business cycle against (the possibility of) having to incur higher variable costs (e.g., use of higher cost overtime and third-shift operations) during periods of strong demand. As a consequence, GM's break-even output point declined sharply.

¹⁴Jacob M. Schlesinger, "GM to Reduce Capacity to Match Its Sales," *Wall Street Journal* (April 25, 1988), p. 2; Lawrence Ingrassia and Joseph B. White, "GM Plans to Close 21 More Factories, Cut 74,000 Jobs, Slash Capital Spending," *Wall Street Journal* (December 19, 1991), p. A3; and "A Duo of Dunces," *The Economist* (March 9, 2002), p. 63.

Doing a Break-Even versus a Contribution Analysis

A break-even analysis assumes that all types of costs except the narrowly defined incremental variable cost (V) of additional unit sales are avoidable and asks the question of whether sufficient unit sales are available at the contribution margin ($P - V$) to cover all these relevant costs. If so, they allow the firm to earn a net profit. These questions normally arise at entry and exit decision points where a firm can avoid essentially all its costs if the firm decides to stay out or get out of a business. Contribution analysis, in contrast, applies to questions such as whether to adopt an advertising campaign, introduce a new product, shut down a plant temporarily, or close a division. What distinguishes these contribution analysis questions is that many fixed costs remain unavoidable and are therefore irrelevant to the decision (indirect fixed costs), while other fixed costs will be newly committed as a result of the decision (direct fixed costs) and therefore could be avoided by refusing to go ahead with the proposal.

More generally, contribution analysis always asks whether enough additional revenue arises from the ad campaign, the new product, or the projected sales of the plant or division to cover the direct fixed plus variable costs. That is, **contribution analysis** calculates whether sufficient gross operating profits result from the incremental sales (ΔQ) attributable to the ad, the new product, or the promotion to offset the proposed increase in fixed cost. In other words, are the total contributions to cover fixed cost increased by an amount greater than the increase in direct fixed cost avoidable by the decision?

contribution analysis

A comparison of the additional operating profits to the direct fixed costs attributable to a decision.

$$\begin{aligned} (P - V) \Delta Q &> \Delta \text{ Total Fixed Cost} \\ &> \Delta \text{ Indirect Fixed Cost} + \Delta \text{ Direct Fixed Cost} && [9.12] \\ &> 0 + \Delta \text{ Direct Fixed Cost} \end{aligned}$$

Such decisions are not break-even decisions because they ignore (abstract from) the indirect fixed costs that, by definition, cannot be avoided by rejecting the ad campaign or new product introduction proposal or by closing the plant temporarily. For example, headquarters facility cost and other corporate overhead are indirect fixed costs that cannot be avoided by any of these decisions. So, corporate overhead is not a relevant cost in making these decisions and is therefore ignored in the contribution analysis done to support making such decisions.

In contrast, corporate overhead is prominent in the preceding examples of break-even analysis done to decide how or whether to enter a new business in the first place. Business certification, licensing, or franchise fees would be a good example of this concept of corporate overhead. The case exercise on charter airline operating decisions at the end of this chapter illustrates the use of contribution analysis as distinguished from break-even analysis.

Some Limitations of Break-Even and Contribution Analysis

Break-even analysis has a number of limitations that arise from the *assumptions* made in constructing the model and developing the relevant data.

Composition of Operating Costs In doing break-even analysis, one assumes that costs can be classified as either fixed or variable. In fact, some costs are partly fixed and partly variable (e.g., utility bills). Furthermore, some fixed costs increase in a stepwise manner as output is increased; they are *semivariable*. For example, machinery maintenance is scheduled after 10 hours or 10 days or 10 weeks of use. These direct fixed costs must be considered variable if a batch production decision entails this much use.

Example**Taco Bell Chihuahua Drives Sales**

Consider the Taco Bell ad campaign with the cute little dog that was designed to pulse twenty-five 15-second spot commercials over several weeks. The ad agency quoted a cost of \$750,000 per spot to secure prime-time network television reaching 176 million households. To decide whether to buy this ad campaign, we need to know just two things: (1) the incremental sales that demand analysis suggests will be stimulated by this campaign and (2) the contribution margin in dollars. Suppose the incremental sales are estimated at 2,100 Taco Bell meals per day for 90 days across 48 states, totaling 9,072,000 meals. If \$7.99 is the average price per realized unit sale and variable costs are \$5.00, should Taco Bell go ahead with the ad? The answer is yes, because when we apply Equation 9.12,

$$(\$7.99 - \$5.00) 9,072,200 > 0 + (25 \times \$750,000)$$

$$\$27,125,280 > \$18,750,000$$

we see that Taco Bell would increase its operating profit by \$8.4 million and make further contributions toward covering fixed cost and profit if it authorized the proposed ad campaign.

Multiple Products The break-even model also assumes that a firm is producing and selling either a *single* product or a *constant mix* of different products. In many cases the product mix changes over time, and problems can arise in allocating fixed costs among the various products.

Uncertainty Still another assumption of break-even analysis is that the selling price and variable cost per unit, as well as fixed costs, are known at each level of output. In practice, these parameters are subject to uncertainty. Thus, the usefulness of the results of break-even analysis depends on the accuracy of the estimates of the future selling price and variable cost.

Inconsistency of Planning Horizon Finally, break-even analysis is normally performed for a planning period of one year or less; however, the benefits received from some costs may not be realized until subsequent periods. For example, research and development costs incurred during a specific period may not result in new products for several years. For break-even analysis to be a dependable decision-making tool, a firm's operating costs must be matched with resulting revenues for the planning period under consideration.

operating leverage The use of assets having fixed costs (e.g., depreciation) in an effort to increase expected returns.

degree of operating leverage (DOL) The percentage change in a firm's earnings before interest and taxes (EBIT) resulting from a given percentage change in sales or output.

Operating Leverage

Operating leverage involves the use of assets that have fixed costs. A firm uses operating leverage in the hope of earning returns in excess of the fixed costs of the assets, thereby increasing the returns to the owners of the firm. A firm's **degree of operating leverage (DOL)** is defined as the multiplier effect resulting from the firm's use of fixed operating costs. More specifically, DOL can be computed as the *percentage change* in earnings before interest and taxes (EBIT) resulting from a given *percentage change* in sales (output):

$$\text{DOL at } Q = \frac{\text{Percentage change in EBIT}}{\text{Percentage change in Sales}}$$

This relationship can be rewritten as follows:

$$\text{DOL at } Q = \frac{\frac{\Delta \text{EBIT}}{\text{EBIT}}}{\frac{\Delta \text{Sales}}{\text{Sales}}} \quad [9.13]$$

where ΔEBIT and ΔSales are the changes in the firm's EBIT and Sales, respectively.

Because a firm's DOL differs at each sales level, it is necessary to indicate the sales point, Q , at which operating leverage is measured. The degree of operating leverage is analogous to the elasticity of demand concept (e.g., price and income elasticities) because it relates percentage changes in one variable (EBIT) to percentage changes in another variable (sales). Equation 9.13 requires the use of two different values of sales and EBIT. Another equation (derived from Equation 9.13) that can be used to compute a firm's DOL more easily is

$$\text{DOL at } Q = \frac{\text{Sales} - \text{Variable costs}}{\text{EBIT}} \quad [9.14]$$

The variables defined in the previous section on break-even analysis can also be used to develop a formula for determining a firm's DOL at any given output level. Because sales are equivalent to TR (or $P \times Q$), variable cost is equal to $V \times Q$, and EBIT is equal to total revenue (TR) less total (operating) cost, or $(P \times Q) - F - (V \times Q)$, these values can be substituted into Equation 9.14 to obtain the following:

$$\text{DOL at } Q = \frac{(P \cdot Q) - (V \cdot Q)}{(P \cdot Q) - F - (V \cdot Q)}$$

or

$$\text{DOL at } Q = \frac{(P - V)Q}{(P - V)Q - F} \quad [9.15]$$

Business Risk

business risk The inherent variability or uncertainty of a firm's operating earnings (earnings before interest and taxes).

Business risk refers to the inherent variability or uncertainty of a firm's EBIT. It is a function of several factors, one of which is the firm's DOL. The DOL is a measure of how sensitive a firm's EBIT is to changes in sales. The greater a firm's DOL, the larger the change in EBIT will be for a given change in sales. Thus, *all other things being equal*, the higher a firm's DOL, the greater the degree of business risk.

Other factors can also affect a firm's business risk, including the variability or uncertainty of sales. A firm with high fixed costs and stable sales will have a high DOL, but it will also have stable EBIT and, therefore, low business risk. Public utilities and pipeline transportation companies are examples of firms having these operating characteristics.

Another factor that may affect a firm's business risk is uncertainty concerning selling prices and variable costs. A firm having a low DOL can still have high business risk if selling prices and variable costs are subject to considerable variability over time. A cattle feedlot illustrates these characteristics of low DOL but high business risk; both grain costs and the selling price of beef at times fluctuate wildly.

In summary, a firm's DOL is only one of several factors that determine the firm's business risk.


Example

Operating Leverage: Allegan Manufacturing Company (continued)

In the earlier discussion of break-even analysis for the Allegan Manufacturing Company, the parameters of the break-even model were determined as $P = \$250/\text{unit}$, $V = \$150/\text{unit}$, and $F = \$1,000,000$. Substituting these values into Equation 9.15 along with the respective output (Q) values yields the DOL values shown in Table 9.2. For example, a DOL of 6.00 at an output level of 12,000 units indicates that from a base output level of 12,000 units EBIT will increase by 6.00 percent for each 1 percent increase in output.

Note that Allegan's DOL is largest (in absolute value terms) when the firm is operating near the break-even point (where $Q = Q_b = 10,000$ units). Note also that the firm's DOL is negative below the break-even output level. A negative DOL indicates the percentage *reduction* in operating losses that occurs as the result of a 1 percent *increase* in output. For example, the DOL of -1.50 at an output level of 6,000 units indicates that from a base output level of 6,000 units the firm's operating losses will be *reduced* by 1.5 percent for each 1 percent *increase* in output.

A firm's DOL is a function of the nature of the production process. If the firm employs large amounts of equipment in its operations, it tends to have relatively high fixed operating costs and relatively low variable operating costs. Such a cost structure yields a high DOL, which results in large operating profits (positive EBIT) if sales are high and large operating losses (negative EBIT) if sales are depressed.

TABLE 9.2 DOL AT VARIOUS OUTPUT LEVELS FOR ALLEGAN MANUFACTURING COMPANY

OUTPUT Q	DEGREE OF OPERATING LEVERAGE (DOL)
0	0
2,000	-0.25
4,000	-0.67
6,000	-1.50
8,000	-4.00
10,000	(undefined) Break-even level
12,000	+6.00
14,000	+3.50
16,000	+2.67
18,000	+2.25
20,000	+2.00

Break-Even Analysis and Risk Assessment

The break-even unit sales figure can also be used to assess the business risk to which a firm is exposed. If one forecasts the mean unit sales for some future period of time, the standard deviation of the distribution of unit sales, and makes an assumption about how

Example**Business Risk Assessment: Allegan Manufacturing Company (continued)**

For the Allegan Manufacturing Company discussed earlier, suppose that expected sales are 15,000 units with a standard deviation of 4,000 units. Recall that the break-even volume was 10,000 units. Substituting $Q_b = 10,000$, $\bar{Q} = 15,000$, and $\sigma_Q = 4,000$ into Equation 9.16 yields

$$\begin{aligned} z &= \frac{10,000 - 15,000}{4,000} \\ &= -1.25 \end{aligned}$$

In other words, the break-even sales level of 10,000 units is 1.25 standard deviations *below* the mean. From Table 1 in Appendix B, the probability associated with -1.25 standard deviations is 0.1056 or 10.56 percent. Thus, Allegan faces a 10.56 percent chance that it will incur operating losses and an 89.44 percent chance ($100 - 10.56$ percent chance of losses) that it will record operating profits from selling more than the break-even number of units of output.

actual sales are distributed, one can compute the probability that the firm will have operating losses, meaning it will sell fewer units than the break-even level.

The probability of having operating losses (selling fewer than Q_b units) can be computed using the following equation and the standard normal probability distribution as

$$z = \frac{Q_b - \bar{Q}}{\sigma_Q} \quad [9.16]$$

where the probability values are from Table 1 in Appendix B, \bar{Q} is the expected unit sales, σ_Q is the standard deviation of unit sales, and Q_b is (as defined earlier) the break-even unit sales. The probability of operating profits (selling more than Q_b units) is equal to 1 minus the probability of operating losses.

SUMMARY

- In estimating the behavior of short-run and long-run cost functions for firms, the primary methodological problems are (1) differences in the manner in which economists and accountants define and measure costs and (2) accounting for other variables (in addition to the output level) that influence costs.
- Many statistical studies of *short-run* cost-output relationships suggest that total costs increase linearly (or quadratically) with output, implying constant (or rising) marginal costs over the observed ranges of output.
- Many statistical studies of *long-run* cost-output relationships indicate that long-run cost functions are L-shaped. Economies of scale (declining average costs) occur at low levels of output. Thereafter, long-run average costs remain relatively constant over large ranges of output. Diseconomies of scale are observed in only a few cases, probably because few firms can survive with costs attributable to excessive scale.
- *Engineering cost techniques* are an alternative approach to statistical methods in estimating long-run cost functions. With this approach, knowledge

of production facilities and technology is used to determine the least-cost combination of labor, capital equipment, and raw materials required to produce various levels of output.

- The *survivor technique* is a method of determining the optimum size of firms within an industry by classifying them by size and then calculating the share of industry output coming from each size class over time. Size classes whose share of industry output is increasing over time are considered to be more efficient and to have lower average costs.
- *Break-even analysis* is used to examine the relationship among a firm's revenues, costs, and operating profits (EBIT) at various output levels. Frequently the analyst constructs a break-even chart based on linear cost-output and revenue-output relationships to determine the operating characteristics of a firm over a limited output range.
- The *break-even point* is defined as the output level at which total revenues equal total costs of operations. In the linear break-even model, the break-

even point is found by dividing fixed costs by the difference between price and variable cost per unit, the *contribution margin*.

- *Contribution analysis* is used to examine operating profitability when some fixed costs (indirect fixed costs) cannot be avoided and other direct fixed costs can be avoided by a decision. Decisions on advertising, new product introduction, shutdown, and downsizing are often made by doing a contribution analysis.
- *Operating leverage* occurs when a firm uses assets having fixed operating costs. The *degree of operating leverage* (DOL) measures the percentage change in a firm's EBIT resulting from a 1 percent change in sales (or units of output). As a firm's fixed operating costs rise, its DOL increases.
- *Business risk* refers to the variability of a firm's EBIT. It is a function of several factors, including the firm's DOL and the variability of sales. All other things being equal, the higher a firm's DOL, the greater is its business risk.

Exercises

Answers to the exercises in blue can be found in Appendix C at the back of the book.

1. A study of 86 savings and loan associations in six northwestern states yielded the following cost function:¹⁵

$$C = \underset{(2.84)}{2.38} - \underset{(2.37)}{.006153Q} + \underset{(2.63)}{.000005359Q^2} + \underset{(2.69)}{19.2X_1}$$

where C = average operating expense ratio, expressed as a percentage and defined as total operating expense (\$ million) divided by total assets (\$ million) times 100 percent

Q = output, measured by total assets (\$million)

X_1 = ratio of the number of branches to total assets (\$million)

Note: The number in parentheses below each coefficient is its respective t -statistic.

- a. Which variable(s) is(are) statistically significant in explaining variations in the average operating expense ratio?
- b. What type of cost-output relationship (e.g., linear, quadratic, or cubic) is suggested by these statistical results?
- c. Based on these results, what can we conclude about the existence of economies or diseconomies of scale in savings and loan associations in the Northwest?

¹⁵Holton Wilson, "A Note on Scale Economies in the Savings and Loan Industry," *Business Economics* (January 1981), pp. 45–49.

2. Referring to Exercise 1 again:
 - a. Holding constant the effects of branching (X_1), determine the level of total assets that minimizes the average operating expense ratio.
 - b. Determine the average operating expense ratio for a savings and loan association with the level of total assets determined in Part (a) and 1 branch. Same question for 10 branches.
3. A study of the costs of electricity generation for a sample of 56 British firms in 1946–1947 yielded the following long-run cost function:¹⁶

$$AVC = 1.24 + .0033Q + .0000029Q^2 - .000046QZ - .026Z + .00018Z^2$$

where AVC = average variable cost (i.e., working costs of generation), measured in pence per kilowatt-hour (kWh). (A pence was a British monetary unit equal, at that time, to 2 cents U.S.)

Q = output, measured in millions of kWh per year
 Z = plant size, measured in thousands of kilowatts

- a. Determine the long-run variable cost function for electricity generation.
 - b. Determine the long-run marginal cost function for electricity generation.
 - c. Holding plant size constant at 150,000 kilowatts, determine the short-run average variable cost and marginal cost functions for electricity generation.
 - d. For a plant size equal to 150,000 kilowatts, determine the output level that minimizes short-run average variable costs.
 - e. Determine the short-run average variable cost and marginal cost at the output level obtained in Part (d).
4. Assuming that all other factors remain unchanged, determine how a firm's break-even point is affected by each of the following:
 - a. The firm finds it necessary to reduce the price per unit because of increased foreign competition.
 - b. The firm's direct labor costs are increased as the result of a new labor contract.
 - c. The Occupational Safety and Health Administration (OSHA) requires the firm to install new ventilating equipment in its plant. (Assume that this action has no effect on worker productivity.)
5. Cool-Aire Corporation manufactures a line of room air conditioners. Its break-even sales level is 33,000 units. Sales are approximately normally distributed. Expected sales next year are 40,000 units with a standard deviation of 4,000 units.
 - a. Determine the probability that Cool-Aire will incur an operating loss.
 - b. Determine the probability that Cool-Aire will operate above its break-even point.
6. McKee Corporation has annual fixed costs of \$12 million. Its variable cost ratio is .60.
 - a. Determine the company's break-even dollar sales volume.
 - b. Determine the dollar sales volume required to earn a target profit of \$3 million.

¹⁶Johnston, *Statistical Cost Analysis*, Chapter 4, *op. cit.*

Case Exercises

COST FUNCTIONS

The following cost-output data were obtained as part of a study of the economies of scale in operating a charter high school in Wisconsin:¹⁷

STUDENTS IN AVERAGE DAILY ATTENDANCE	MIDPOINT OF VALUES IN COLUMN A	OPERATING EXPENDITURE PER STUDENT	NUMBER OF SCHOOLS IN SAMPLE
(A)	(B)	(C)	(D)
143–200	171	\$531.9	6
201–300	250	480.8	12
301–400	350	446.3	19
401–500	450	426.9	17
501–600	550	442.6	14
601–700	650	413.1	13
701–900	800	374.3	9
901–1,100	1,000	433.2	6
1,101–1,600	1,350	407.3	6
1,601–2,400	2,000	405.6	7

Questions

- Plot the data in columns B and C in an output (enrollment-) cost graph and sketch a smooth curve that would appear to provide a good fit to the data.
- Based on the scatter diagram in Question 1, what kind of mathematical relationship would appear to exist between enrollment and operating expenditures per student? In other words, do operating expenditures per student appear to (i) be constant (and independent of enrollment), (ii) follow a linear relationship as enrollment increases, or (iii) follow some sort of nonlinear U-shape (possibly quadratic) relationship as enrollment increases?

As part of this study, the following cost function was developed:

$$C = f(Q, X_1, X_2, X_3, X_4, X_5)$$

where C = operating expenditures per student in average daily attendance (measured in dollars)

Q = enrollment (number of students in average daily attendance)

X_1 = average teacher salary

X_2 = number of credit units (“courses”) offered

X_3 = average number of courses taught per teacher

X_4 = change in enrollment between 1957 and 1960

X_5 = percentage of classrooms built after 1950

Variables X_1 , X_2 , and X_3 were considered measures of teacher qualifications, breadth of curriculum, and the degree of specialization in instruction, respectively. Variable X_4 measured changes in demand for school services that could cause some lagging adjustments in cost. Variable X_5 was used to reflect any

¹⁷John Riew, “Economies of Scale in High School Operation,” *Review of Economics and Statistics* 48:3 (August 1966), pp. 280–287.

differentials in the costs of maintenance and operation due to the varying ages of school properties. Statistical data on 109 selected high schools yielded the following regression equation:

$$C = 10.31 - .402Q + .00012Q_2 + .107X_1 + .985X_2 + 15.62X_3 + .613X_4 - .102X_5$$

$$\begin{array}{cccccccc} & (6.4)^* & (5.2)^* & (8.2)^* & (.15) & (1.3) & (3.2)^* & (.93) \end{array}$$

$$r^2 = .557$$

Notes: The numbers in parentheses are the t-scores of each of the respective (b) coefficients. An asterisk (*) indicates that the result is statistically significant at the 0.01 level.

3. What type of cost-output relationship (linear, quadratic, cubic) is suggested by these statistical results?
4. What variables (other than enrollment) would appear to be most important in explaining variations in operating expenditures per student?
5. Holding constant the effects of the other variables (X_1 through X_5), determine the enrollment level (Q) at which average operating expenditures per student are minimized. (*Hint:* Find the value of Q that minimizes the $\partial C/\partial Q$ function.)
6. Again, holding constant the effects of the other variables, use the $\partial C/\partial Q$ function to determine, for a school with 500 students, the reduction in per-student operating expenditures that will occur as the result of adding one more student.
7. Again, holding the other variables constant, what would be the saving in per-student operating expenditures of an increase in enrollment from 500 to 1,000?
8. Based on the results of this study, what can we conclude about the existence of economies or diseconomies in operating a public high school?

CHARTER AIRLINE OPERATING DECISIONS

Firm-specific demand in the *scheduled airline industry* is segmented by customer class and is highly uncertain so that an order may not lead to realized revenue and a unit sale. Airlines respond to this dynamic, highly competitive environment by tracking reservations at preannounced fares and reassigning capacity to the various market segments (“buckets”) as business travelers, vacationers, and convention groups book the flights above or below expected levels several days and even weeks before scheduled departure. This systems management process combining marketing, operations, and finance is referred to as revenue management or yield management and is discussed in Chapter 14.

The *charter airline business*, on the other hand, is much less complicated because capacity requirements are known far in advance, and all confirmed orders lead to realized revenue. We consider the following three decisions for a charter airline: (1) the entry/exit break-even decision, (2) the operate/shut down decision to fly/not fly a charter that has been proposed, and (3) the output decision as to how many incremental seats to sell if the airline decides to operate the charter flight.

Suppose the following costs for a 10-hour round-trip flight apply to the time frame and expenses of an unscheduled 5-hour charter flight from Baltimore to Las Vegas (and return the next day) on a seven-year-old Boeing 737-800 with 120 occupied

seats.¹⁸ Some costs listed in the table have been aggregated up to the flight level from a seat-level decision where they are incurred. Others have been allocated down to the flight level from an entry/exit or maintain ownership company-level decision. Still other costs vary with the go/no go flight-level decision itself. Your job is to analyze each cost item and figure out the “behavior of cost”—that is, with which decision each cost varies.

Fuel and landing fees	\$5,200
Quarterly airframe maintenance re: FAA certificate	1,000
Unscheduled engine maintenance per 10 flight hours	1,200
Pro rata time depreciation for 7th year of airframe	7,200
Flight pay for pilots per round-trip flight	4,200
Long-term hangar facility lease	6,600
Annual aircraft engine operating lease	7,100
Base salaries of headquarters personnel	2,000
Food service with seat-by-seat purchase and JIT delivery at each departure	2,400
Airport ground crew baggage handling for two flight arrivals	450

Questions

1. What are the variable costs for the decision to send one more person aboard a charter flight that is already 80 percent booked?
2. In making an entry/exit decision, if competitive pressure is projected to force the price down to \$300, what is the break-even unit sales volume this company should have projected as part of its business plan before entering this market and should reconsider each time it considers leaving (exiting) this business altogether?
3. Identify the indirect fixed costs of the charter service for a particular one of many such charters this month.
4. If one were trying to decide whether to operate (fly) or not fly an unscheduled round-trip charter flight, what would be the total direct fixed costs and variable costs of the flight?
5. Charter contracts are negotiable, and charter carriers receive many contract offers that do not promise \$300 prices or 80-percent-full planes. Should the airline accept a charter flight proposal from a group that offers to guarantee the sale of 90 seats at \$250? Why or why not?
6. What are the total contributions of the charter flight with 90 seats at \$250 per seat?
7. What are the net income losses for this two-day period if the airline refuses the 90-seat charter, stays in business, but temporarily shuts down? What are the net income losses if it decides to operate and fly the charter that has been proposed?
8. What is the segment-level contribution of a separate group that is willing to join the 90-seat-at-\$250-per-seat charter on the same plane and same departure, but only wishes to pay \$50 per seat for 10 seats?
9. Should you accept their offer? What problems do you anticipate if both charter groups are placed on the 737?

¹⁸The aerodynamics of the plane and its fuel efficiency do change as the number of seats occupied falls below 180, but you may ignore this effect.